ANALYSIS OF RISK MANAGEMENT STRATEGIES IN THE DAIRY INDUSTRY USING MONTE CARLO SIMULATION TECHNIQUES

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

James Harvey Neyhard

February 2010

ABSTRACT

Market prices for both milk and feed commodities exhibit increasing volatility in recent years thus creating additional uncertainty in the management of dairy farms. This uncertainty translates to financial and business risk for the dairy manager as the ability to accurately budget future investments and to meet debt obligations is hindered by rapidly changing commodity prices.

Three years of data from the Dairy Farm Business Summary, conducted annually by Cornell University, was used to develop financial statements for a 1,000 cow dairy. Historical commodity futures and options data, gathered by the University of Wisconsin, was used to develop price distributions and volatility estimates for milk, corn, and soybean meal. Combinations of risk management tools such as futures contracts and options were then analyzed against various price paths to primarily determine their relative efficacies in reducing the variance in annual net farm income. These price paths were generated through Monte Carlo simulation techniques using the @Risk add-in for Microsoft Excel.

Analysis of the risk management tools spanned three levels of leverage from 20% to 70% as well as three marketing environments which were defined by volatility parameter and level of hedging. Thus nine simulations were completed in order to test the robustness of the risk management tools against changes in market assumptions and farm type.

Results of the model generally fall in line those predicted by hedging theories. Average net farm income was lower when using risk management tools when compared to the baseline of cash marketing strategies. However, the variance in net farm income was reduced by using risk management tools. The effectiveness of the risk management tools differed among the various simulations and also based on the

measure of effectiveness being used. In general, the use of futures contracts resulted in the greatest reduction in net farm income variance while the use of options provided a floor to net farm income while at the same time allowing for upside potential.

This work provides a unique structural approach to modeling the use of risk management tools by dairy managers. The structure presented in this thesis mimics the daily price changes faced by producers and thus closely resembles their decision environment. The generation of daily prices allows for a full estimation of hedging costs, which is one of the main contributions of this thesis. The structure of the model also contributes to the literature regarding risk management by recreating the flow of a basic marketing plan by allowing the decision maker to determine their price triggers, times, and levels at which hedging takes place. This structure will likely contribute to further research through its flexibility in price generating parameters and marketing plan decision points.

BIOGRAPHICAL SKETCH

James Harvey Neyhard was born February 4, 1982 in Lewisburg, PA. James, known to most as “Jim”, graduated from Warrior Run High School in June 2000.

After dabbling in various undergraduate majors such as bio-chemistry and animal science, Jim was granted the degree of Bachelor of Science from The Pennsylvania State University in the field of Environmental and Renewable Resource Economics in 2004.

Jim will earn a Master of Science in Applied Economics and Management from Cornell University in January 2010. Following this he will continue his lifelong pursuit of knowledge through the home schooling system where the subjects covered are sure to include the philosophy of science, investment analysis for the indecisive, cooking with exotic spices, the sport of running, the psychology of personal finance, strategy development for agricultural firms, a survey of political and economic philosophies throughout history, appreciation of randomness and other finer things, do it yourself renovation and preservation of historic homes, as well as the core courses of faith, love, and marriage.

To Black Swans, little brown spiders, and Registered Holsteins for teaching me the true meaning of risk and success. This thesis is particularly indebted to the dairy farmers of New York and the coffee farmers of the world.

ACKNOWLEDGEMENTS

This thesis is the culmination of the efforts of many individuals. My full appreciation to each is inexpressible, but I hope this pithy attempt to do so is recognized by those mentioned as a means to preserve my gratitude through the written word, which I believe to be one of the greatest, and yet underappreciated, treasures of mankind.

First and foremost I would like to thank my family for instilling in me an unquenchable thirst for learning and knowledge. My belief in and pursuit of continual self-improvement owes much to those whom have known and loved me from the day I was born. I am forever grateful for these treasures.

Of course no thesis could be completed without the watchful guidance and support of academic advisors. I thank my committee chairman, Dr. Loren Tauer, for his insight in developing a thesis topic inclusive of both my academic and career interests. I am grateful for both his precise commentary in helping to refine the final product and also his trust in allowing me the freedom to determine the path and structure this work would take in order to accomplish its objectives. This guidance proved its value not only in the completion of this work but more importantly in helping me recognize the value and reward of complete investment of oneself in research questions and in all undertakings in life.

My second advisor, Dr. Brent Gloy, provided invaluable feedback regarding the development of this thesis. With enough coffee, discussions with Dr. Gloy always proved fruitful whether they addressed the philosophical definitions of risk or simply the best way to just get to the point in any given paragraph of this thesis. I will forever be indebted for the books. While they may have unintentionally helped to extend the completion date of this thesis, perhaps more importantly they provided me with a stronger appreciation with just how fragile the balance is between the world we live in and the world we convince ourselves we understand. Life and uncertainty should be valued each and every day. Thank you for reminding me.

The Morgenthau family deserves particular praise for their financial contributions to Cornell University. My time at Cornell was made possible in part through their generosity.

I would also like to thank Dr. Wayne Knoblauch for reminding me to always plan first. I am grateful for the lessons I learned from this cantankerous PhD with a cowboy hat from the applied and useful side of economics.

The help, and patience, of Linda Morehouse in guiding me through all of the forms and processes required to make oneself a graduate student is greatly appreciated. Your tremendous care and concern for the graduate students at Cornell University does not go unnoticed.

My sincere appreciation goes out to the management and employees of a dairy farm located just north of Ithaca. Some of my fondest memories happened within the time of my employment there. The lessons of hard work, commitment, continual learning, and where to find the best sandwiches and hot wings in the state of New York will never be forgotten.

For the love of my life I reserve my final and greatest thanks. Becky Graves provided me with the love and support I needed during my work on this thesis. She sacrificed and gave more than any woman should be asked to during these long years and for that I am forever thankful. Becky, without you I would not have made it here nor would there be so many places I look forward to as we journey through life together. All that can be said is thank you. I love you, so much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: INTRODUCTION

Background and Overview

Management of dairy farms is a demanding task requiring the manager to determine optimal use of physical capital, including land and cows, labor, and financial capital. Coordination of these resources results in a valuable output, milk. Optimizing the use and investment in each of these resources requires calculated efforts by decision makers at both the operational and strategic levels of management. These efforts are directed based upon the information available to the decision maker up to the time a decision must be made. Incomplete information such as rapidly and unexpectedly changing prices or production levels impacts the quality of decisions and directly affects the wellbeing of the business and its stakeholders. The combination of incomplete information and its subsequent impact on the strength and survival of the business serves as the practical definition of risk for the purposes of this thesis. In particular, this thesis considers the specific risks presented by volatile prices for milk and purchased feed commodities and examines the potential benefits and costs of strategically managing these risks.

The volatility of both milk and feed prices has become more pronounced over the last quarter century. Some of the increased volatility is due to market transformations such as the increased role of exports for the United States dairy industry (Miller and Blayney). However, arguments can be made that the dairy industry has historically been a highly volatile environment and the recently decreased government safety nets have simply revealed more of the natural economic character of the industry over recent years (Stephenson and Nicholson).

Regardless of the outcome of this debate, milk and feed prices are not predictable and thus represent an area of incomplete information to the decision maker. The impacts of these uncertainties may include increased variance in cash flows and profitability, which in turn hinder the capital budgeting abilities of the decision maker (Bailey; Miller and Blayney). In total these impacts may lead to the ultimate risk of business survival. The following figure based on monthly milk prices in the state of New York, from the National Agricultural Statistics Service – USDA, demonstrates the increasing rapidity and magnitude of changes observed in milk prices.

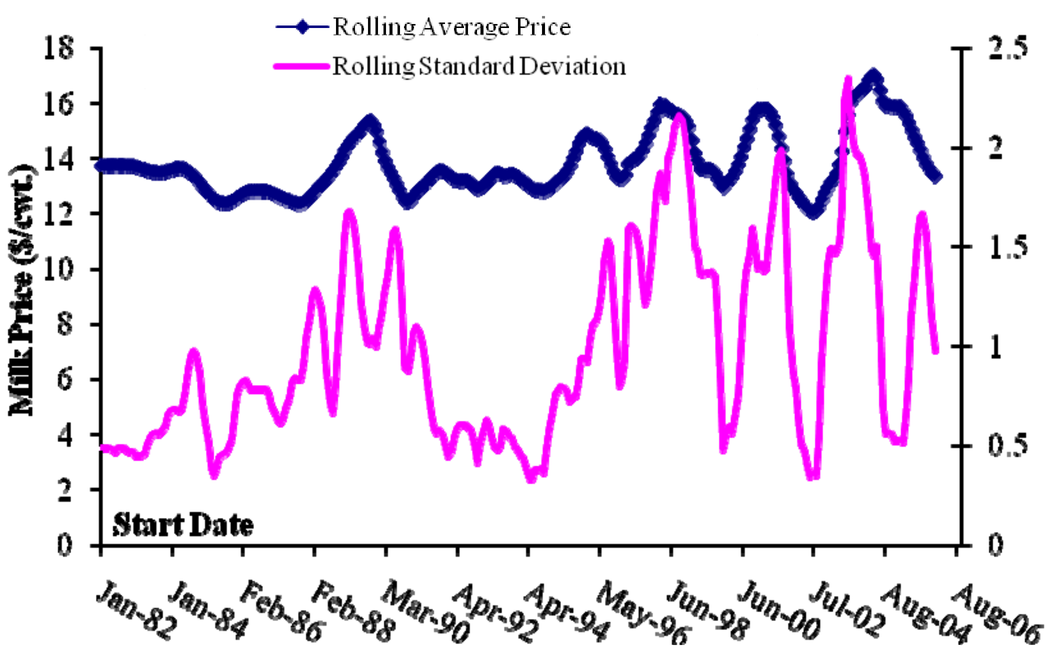

Figure 1. Rolling (12 month) Mean and Standard Deviation, Monthly Milk Price

As shown, the magnitude of changes for the rolling twelve month average and standard deviation has increased while the time between such swings decreased. These are signs of increased volatility, rapid and unexpected changes, in the market place.

Statement of the Problem

Market price volatility is a source of incomplete information to dairy managers. Incomplete price information introduces uncertainty at both the operational and strategic levels of management. If the effect of this uncertainty then impedes the business from meeting its goals, it can be said to represent a risk to the business and its stakeholders. For this reason, a dairy manager must choose an approach towards the potential risks brought on by unpredictable prices. While risk management has come to be seen as a discipline in and of itself, this work considers risk management as a process for dealing with incomplete information within the context of other management areas such as operational or strategic planning. In this light, a dairy manager does not develop a price risk management plan simply to reduce the variance of prices, but instead develops the plan from the perspective of managing prices in order to accomplish an overarching goal of the farm business (Olson).

Reiterated throughout this work, is the idea that understanding how risk is defined directly affects the manner in which it is analyzed and managed. Despite voluminous efforts to describe various pieces of the risk management process such as commodity price behavior or the calculation of optimal hedge ratios, limiting the definition of risk to include only the variance of prices has resulted in very little literature available to dairy managers regarding a whole-farm approach to risk management. In addition, the full costs of hedging such as margin calls are typically afforded only scant attention. This lack of information regarding the full costs of various risk management strategies and their whole farm impacts forces the dairy manager to make decisions with incomplete evidence and information. That limitation will be addressed in this work. Hedging and other risk management approaches are not costless activities and thus require the use of financial capital. In order to analyze various risk management strategies in an equivalent manner to other capital investments, the decision maker requires information on the investments required and the associated returns. These areas are addressed in this thesis in order to aid the decision maker in constructing a more complete analysis of various risk management strategies.

The structure of the model employed in this thesis is the central contribution of this work. The flexible, simulation-based model yields other unique contributions to the academic literature on risk management in the following ways. First, this work treats hedging and other risk management approaches as selective, as opposed to routine, processes to achieve specific business goals. Second, this work examines the interrelationships between the financial situation of the farm, chosen risk management strategies, and the whole-farm effects of these strategies. Finally, this work provides distributions for both total risk management costs and associated returns on investment for various combinations of risk management tools.

Objectives and Methods Overview

This thesis aims to explicitly demonstrate the potential impacts of milk and feed price volatility on the financial situation of a dairy farm. In addition, it aims to exhibit the potential range of costs and returns for a set of selective risk management strategies developed within the context of a basic marketing plan built upon the production and financial information of the farm as well as assumed goals of the dairy manager. Accomplishment of these objectives provides dairy managers with a quantitative benchmark with which to compare their own approach to managing volatile commodity prices. This work demonstrates how changes in the assumptions, such as volatility, of price behavior and the beginning financial situation, such as equity, of the farm may affect the net benefits of each risk management tool examined as well as the ending financial situation of the farm.

These objectives are achieved by applying Monte Carlo simulation techniques to a set of pro-forma financial statements and a basic marketing plan. The pro-forma financial statements are developed to represent a 1,000 cow dairy. These financial statements include a cash flow budget, income statement and balance sheet, and are developed using relevant data from the Dairy Farm Business Summary (Knoblauch, et al.). A basic marketing plan is then developed contingent upon the financial status and goals of the farm. The outputs of this marketing plan are triggers, based on relative commodity price levels, which can be used by the dairy manager as signals to employ or refrain from the use of various risk management tools. The @Risk add-in for Excel is then used to simulate the daily prices for milk, corn and soybean meal. Finally the model uses these simulated prices to analyze the effectiveness of various risk management tool combinations employed within a basic marketing plan.

In order to use simulation techniques in analyzing the whole farm effects of the marketing plan and risk management tools, milk price and purchased feed commodity prices are defined as stochastic variables in the financial statements. A basic ration is used as a means to convert commodity prices to a purchased feed line item expense, while milk cow numbers and daily milk production per cow are treated as constants in order to bring the simulated milk prices in as the stochastic revenue component. Feed commodity prices treated as stochastic variables in the financial statements include corn and soybean meal, while other commodities in the ration such as dried distillers grains and alfalfa hay are assigned constant prices. Defining the milk, corn, and soybean meal prices as stochastic allows a dairy manager to gauge the effects of price volatility on a range of various financial measures with particular focus given to net farm income, percent change in equity and borrowings required to meet cash flow demands.

Simulating the daily price path of each commodity allows for the explicit consideration of the potential cost associated with specific risk management strategies, which is one of the stated goals of this work. These strategies are developed within the context of a basic marketing plan. A risk management strategy for the purposes of this work is defined as the combination of a risk management tool, such as a futures contract, and a predetermined price level that triggers a specific use of this tool. The general action employed across all strategies is to fully hedge on a given contract as soon as the associated marketing trigger for that contract is reached. Thus this work isolates the effect of the risk management tools employed by holding constant the marketing trigger and action taken components of each strategy.

The marketing triggers discussed above are defined in the marketing plan based upon the goals of maintaining net worth and meeting cash flow requirements. For the sake of simplicity, only the trigger associated with meeting cash flow demands was used a basis for evaluating risk management strategies in this thesis. The defined strategies are evaluated using simulated price paths in order to gather information on the relative effectiveness of each strategy. In addition, this approach allows for the construction of cost distributions for each of the strategies. These price paths and associated costs of risk management are then used to complete the pro-forma financial statements for all iterations of the simulation. This provides more complete information regarding the possible distributions of the relevant financial measures associated with the use of various risk management strategies while at the same time accounting for the potential costs of these strategies. Information such as this may assist decision makers in more accurately evaluating the use of financial capital for market risk management against other capital investment projects. These steps, marketing plan development and evaluation of risk management tool performance, are repeated across three levels of equity for the modeled dairy farm. This allows exploration of the idea that more highly leveraged operations may have greater incentive to manage the volatility of milk and feed prices.

The contribution of this work is valuable due to its attempt to more accurately reflect the farm level impacts of market risk while at the same time recognizing the costs and returns of various risk management tools. In addition, the use of simulation techniques in this work allows the decision maker to simultaneously evaluate alternative risk management strategies against a large number of price series.

Organization of Thesis

Following the introduction this work proceeds in the following manner. First a review is conducted of the relevant academic literature regarding the handling of risk in agricultural management with emphasis placed on publications specifically addressing risk management on dairy farms. Next the methods used in developing both the coordinated financial statements and the marketing plan simulation model are detailed. Subsequently, the data used in the development of these models is described and summarized. Results of the models are then summarized based upon the various parameters such as hedging levels, debt level of the model farm, and assumed parameters used in generating the price series. Finally the results and their potential implications are discussed in the concluding section. Additional information regarding spreadsheet development and simulation results is presented in the appendices of this work.

CHAPTER II: LITERATURE REVIEW

This chapter serves as a review of the literature to date on the treatment of risk in agricultural models. Components include a brief discussion of the definition of risk, the effects of incomplete information on decision processes, the methods used to incorporate risk into agricultural models and a brief review of dairy system models especially those dealing explicitly with price risk. The aim of this chapter is to help the reader create a general understanding of the progression of thought, theory, and modeling techniques surrounding risk and its management in agricultural production.

As will be seen throughout the remainder of this section, attempts to measure and model risk are numerous. However, defining exactly what is meant by the terms risk or uncertainty has proved to be elusive. This distinction between measurement and definition represents a philosophical debate in the sense of defining or illuminating the meaning of something, rather than an economic differentiation, which would aim to best choose between uncertain options regardless of the comprehensiveness of their definitions. This distinction is worth noting if only to qualify the assumptions and conclusions of this work, others mentioned in it, and any other works the reader may encounter.

Defining Risk

The terms risk and risk management are nothing new to academic literature. Works regarding probability and uncertainty have been around for centuries. While Frank Knight is often cited as providing a definition of risk, it may be more accurate to say he provided a distinction between uncertainty and uncertainty with calculable probability and expected effects, what he termed "risk" (Holton). It is intriguing that a clear definition has yet to be formally adopted. This discrepancy was pointed out by

Holton (2004), who reviewed the progression of philosophical thought surrounding risk and probability theory. He identifies the debate between operational and subjectivist interpretations of probability as being a key driver of this progression. The basic premises of the debate originate from the question of whether probabilities actually exist in nature or whether probabilities are instead the opinion of the observer regarding perceived uncertainty. Objective probabilities are difficult to defend, especially in areas such as business or markets. One could argue that the probabilities found in various forms of gambling represent objective probabilities. As an example, the outcome of a bet dependent on rolling a die is typically assumed to have 1/6 probability of occurring. This would be the case in most casinos. However the preamble to the bet did not reveal that the die was actually constructed of more than six sides. This example helps to illuminate the point that regardless of whether objective probability actually exists, probability as a measure can logically only be used for perceived chance or perceived uncertainty (Holton).

In commodities and finance some of the common measures of perceived price behavior, such as the mean or standard deviation and other statistical moments, are based upon the notion of the Gaussian bell curve. These statistical moments form the distributions used in many of the models incorporating price variation discussed in this section. It is not clear however, that this approach is the most accurate in describing, or forecasting, the behavior of many different types of markets. In many instances, assigning a distribution to a price series may in fact underestimate the likelihood of large jumps in prices or so called outlier events (Taleb). Measuring risk accurately is completely dependent upon understanding the underlying structure generating the perceived behavior of the variable in question. While the measurements of risk have gained in mathematical complexity and precision over recent decades, it is not clear whether these precise parameters accurately reflect the underlying generator of the prices or other variables being measured.

Two general considerations should be made when discussing and analyzing risk in models. First, what was the approach to defining and modeling risk? Second, was the model developed in order to be a normative or positive model? In other words, was the model designed to prescribe what should be the case in managing risk or rather was it structured to describe and encompass what actually occurred (Collins)? A quincunx may be used to demonstrate the building of an approximation for the normal distribution. This tool has a set structure though and thus should yield consistent results, which are inherently predictable as the structure that generates the results is fixed. However this does not appear to be the case in commodity markets and other financial areas. This type of data may require new approaches to modeling its behavior as the observer may be unable to accurately reconstruct the generator as its underlying structure is in constant flux. At the very least, this work echoes the sentiments of Taleb that the observer should be cognizant of the potential difference between the processes behind physical data, such as measuring the height of individuals, and informational data, such as prices. A large portion of statistical theory was developed in order to describe physical phenomena, which reiterates the caution that should be used in applying common statistical rules to non-physical data (Taleb).

This thesis seeks to highlight the fact that due to its inherent nature, we may never be able to fully perceive or adequately define risk or uncertainty, especially in informational arenas such as commodity markets and other asset prices. Therefore it may be more fruitful to accept the reality of uncertainty in life and strengthen the attention paid to contingency planning, strategy formulation, and other means of preserving flexibility in business (Miller et al).

Shortcomings in Evaluating Incomplete Information

Related to the idea of defining risk in order to more accurately model and analyze it, is the idea that the quality of the decision making process is also impacted by the ability of the decision maker to accurately structure the decision, gather appropriate information, and evaluate this information within a justified context. The ability of the decision maker to consistently perform these operations is often hindered by mental or psychological biases related to how the human mind processes information and formulates opinions, these biases or shortcomings are especially apparent as they relate to uncertainty. The literature in psychology and economics, as well as other fields, has increased its volume related to these areas of psychological obstructions to what would classically be termed rational decisions. Several of these shortcomings are especially relevant to the risk management process. These shortcomings include the ability of the decision maker to frame the problem at hand, gathering the most relevant information, and appropriately evaluating the information gathered. These areas are briefly reviewed in this section.

How any situation or decision is framed by the decision maker directly affects the possible solutions considered. The angle from which the problem is viewed and structured is the foundation for any decision process as it determines not only the solutions considered but also the information gathered to help form a resolution (Russo and Schoemaker). In relation to market risk management on dairy farms, framing the problem as a means to ensure reduced variance in net farm income may be accurate but could lead to regret on the part of the decision maker if reduced variance in the short term translates to lower net farm income as well. Although, this view is correct in terms of what would be predicted by economic theory related to hedging, it may not encourage long term acceptance of the possible benefits of hedging.

Alternatively, one could view this reduced variance in net farm income not as an ends but as a means to achieve some goal such as a desired level of cash flow needed to undertake a particular capital investment or in order to meet some other specific financial goal.

How the objectives of risk management are framed and viewed then affects the type of information gathered. If the goal risk management is to reduce variation in net farm income, then a decision maker may focus on information related to variance reduction which may obscure other related information such as potential costs or the time needed to manage a given strategy. While this singular example does not encompass all instances in which the information gathered excludes other relevant areas, it does allow for additional discussion regarding how to frame risk management. If a risk manager were, for example, to view risk management as a means rather than an end, a more holistic view of the performance of risk management strategies and tools would likely be desired by the decision maker.

After information on risk management tools, such as costs, returns, management time required, and other performance measures has been gathered, decision makers must still determine how best to use these tools to accomplish their personal and financial goals. Determining how and when to use risk management tools is directly related to both the goals of the decision maker and the perception held by the decision maker of the price environment in which marketing decisions must be made. While the goals of the decision maker can be considered relatively constant in nature, the prices faced by the decision maker as well as their overall perception of the price environment are relatively unfixed. In dealing with incomplete or random information such as that presented in commodity markets, several cognitive obstructions to objective evaluation of this type of data exist.

These obstructions are related to the disproportionate weight given to historical data, underestimation of probabilities, and anchoring to previous conclusions. Although historical data is useful in building an understanding of what a given price environment was, this information does not necessarily yield additional insight to what the price environment will be in the future. Overweighting historical data as a means to better understanding expected price behavior results in many shortcomings, two of which are narrative biases and anchoring. Narrative biases are caused by the manner in which the human mind stores information. It is much more efficient to mentally recall causative relationships or stories rather than a set of raw data. It is reasonable to assume then that humans may actually default to causative analysis rather than accept that completely random circumstances may have combined to form a given price environment (Taleb). The problem with this is that decision makers will often underestimate risks by assuming past circumstances and causative relationships will repeat themselves in similar ways. The decision maker may also overestimate the likelihood of events if comparable events recently occurred. This bias is caused by the easy recall or vividness of the comparable events (Russo and Schoemaker). In addition to this is the shortcoming of anchoring, which is the attachment to a certain price or perspective beyond objective reason. Often related to the overweighting of historical data, anchoring can often be observed by decision makers looking to only take action if prices are in a historically high range. The drawback with this approach is that the historic benchmark that prices are compared to was conditioned on a previous price environment and information and is not necessarily indicative of what market conditions the decision maker will face in the future as the historically high prices of today can quickly become the low price points of tomorrow. Decision makers can also become anchored to causative explanations as one may cling to certain market analyses such as the historical length of price cycles without considering that the underlying structure of the market may have shifted.

Examination of these biases, though curt in nature, does assist in illustrating how a written marketing plan can benefit dairy managers not only in clearly defining their financial goals but also in curtailing many of the mental biases discussed earlier in this section. A basic marketing plan helps to define goals and the actions needed to achieve these goals. These predefined actions allow the producer to be prepared when opportunities arise in the market place, similar to the manner in which written and understood health protocols allow for immediate action when dealing with herd health situations. In addition, a marketing plan can also include rationale sections which may assist decision makers in more clearly examining why they are choosing a specific market position and have gathered both confirming and disproving information to justify doing so. This approach can help to guard against anchoring to any particular price thus reminding to the decision maker to objectively view whether locking in a given market price merely seems attractive or can actually aid in achieving financial goals. Finally, an integrated marketing plan, such as that presented in this work, looking to achieve a desired margin, may help eliminate some anchoring associated with commodity prices. Using this approach, producers may not anchor themselves to only historically high or low levels in milk and feed prices but will instead look for attractive relative levels of the price to one another. While not preventing or eliminating all decision shortcomings, a written marketing plan with set goals and actions serves as an integral step toward more objectively analyzing and managing incomplete information.

Agricultural Models Incorporating Risk

This section now moves to a concise review of the types of models and approaches taken towards incorporating risk into agricultural decision making. Papers by Collins and Tomek provide the foundation for this review as they each provide a generous overview of the progression of thought regarding hedging and risk management in agriculture. In his 1997 work, Collins provides a review of the types of models based upon the structure of the objective function defined, such as expected utility, and their ability to explain to risk management practices in reality whereas Tomek offers a broader view not only of the types of objective functions used but also of various approaches used in modeling the behavior of commodity prices (Tomek and Peterson; Collins). These papers help form some of the underlying assumptions used in developing this work.

The work by Collins serves as a clear reminder of the difference between normative and positive approaches to developing economic theory and models. In his review, all of the models mentioned took the approach of predicting what the hedging, or risk management, strategies of farmers should be. Recognizing the glaring contrast between the predictions and recommendations made by these models and the observations available of real hedging decisions made by producers, Collins aimed his work at constructing a positive model of risk management. Thus Collins sought to adequately rationalize the actual observation rather than prescribe what should theoretically be optimal actions. In doing this, four criteria were identified that would satisfy a general theory of risk management. These are the no hedge condition, the possibility of conditions encouraging the producer to be fully hedged, a positive relationship between volatility and hedging ratios, and finally a positive relationship between leverage and hedging ratios. These criteria are used in order to develop a model which can explain observed risk management behaviors while at the same time evaluating many of the types of risk management models previously published (Collins).

Several types of models are reviewed in this section including expected utility and Monte Carlo simulation based models among several others. In general, it can be seen that all approaches to modeling risk discussed in this section are foundationally dependent upon assumptions and measures associated with the attitude towards risk of the decision maker and a desirable outcome, such as net farm income, whose variance is thus used as a measure of risk. The first groups of models reviewed by Collins are of the risk minimization and expected utility variety. As will be seen throughout this review, the relationship between the definition of risk and the construction of the objective functions is a key part to understanding the power and limitations of all approaches towards managing risk. If, as in the case of most risk minimization models, risk is defined as cash price variance then the optimal hedge ratio calculated by the models is, as one would guess, based upon an identical but reverse position in the associated futures market (Collins). By defining risk in this manner, these models limit themselves to mathematically expressing a self-prophesied idea as the hedging relationship between futures and cash markets is designed to be offsetting. Thus risk minimization models, when defining risk as variance in cash price, do not allow for the choice of no hedging as an output and thus do not predict a commonly observed practice (Collins).

Works applying these concepts to hedging in the dairy industry also exist. Maynard et al. used a risk minimizing hedge ratio, with respect to futures and cash price variations, in order to examine the Dairy Options Pilot Program funded by the USDA from 1999-2002. Historical data on futures and options from January 2000 –

February 2003 were used in a retroactive simulation to demonstrate the potential reduction in price variance due to the use of futures and options. As one would expect based upon this definition of the problem, a significant reduction in variance was seen through the use of these instruments. Perhaps more importantly, their work presents an excellent overview of the policy drivers and obstacles in creating markets for dairy hedging instruments. In addition, mention is made of the unspoken costs of management time needed to develop marketing strategies and the psychological energies necessary for implementation. In addition, valuable attention is given to discussing the varying results of risk management strategies across regions due to basis and other effects (Maynard et al.). Another work using the basic premises of the risk minimization approach is that by Manfredo and Richards. Their work used simulation techniques to examine the effects of monthly hedging on the financial statements of a dairy cooperative. Valuable insights were provided not only in applying various hedging strategies to the dairy industry but also by presenting their results through various measurements, rather than a singular measure, including mean-variance, Value at Risk, and others (Manfredo and Richards).

Expected utility models and optimal portfolio models have also played a key role in the study of risk management. At their most basic levels these models seek to maximize the idea of utility by optimizing an assumed objective such as net worth or net farm income. In essence, this type of model seeks to optimize the balance between the risk return tradeoff that is acceptable to the decision maker, based upon their attitude towards risk, and the risk minimization relationship between the futures and cash markets. These basically represent the "speculative", where the decision maker may be willing to accept some risk for an anticipated return, and "hedging", where the decision maker looks to transfer risks they are unwilling to accept, portions of any decision associated with price uncertainty (Collins). These models present an intuitive, and perhaps more realistic, view of risk management as a portfolio of tools or strategies that farmers may choose from. However the structure of these models still fails to predict much of the observed risk management practices by farmers, while conversely predicting some actions that are not observed such as large speculative positions taken by individuals with risk neutral attitudes towards risk (Collins).

One surprising result mentioned by Tomek and Peterson, and perhaps a reminder that our ability to accurately model utility or risk attitudes is still limited, was that marketing seminar attendees that initially expressed a preference for risk were actually more likely to use risk reducing tools such as forward pricing. This begs the question as to the actual view farmers hold with respect to risk management tools as this could be interpreted as farmers viewing risk management tools as enhancers rather than stabilizers of net farm income. This apparent inconsistency does however support the idea that farmers look to avoid regret over money left on the table (Tomek and Peterson). Additionally, one could question the application of a general measure of risk aversion and its incorporation into these models. While risk aversion has intuitive appeal and is mathematically efficient for solving these types of models, it has not been without its critics. Many arguments against its use point to outcomes, not predicted by its theory, especially with respect to how choices are framed and how producers incorporate and organize information (Damodoran; Pennings et al.). With respect to dairy farmers specifically, Tauer provided a valuable examination of the risk attitudes of producers in New York State. This work showed roughly equivalent proportions of the sample falling into the categories of risk preferring, risk neutral, and risk aversion characteristics. Causal links between risk attitudes and management decisions, however, were not clear-cut (Tauer). Although this may point to other variables determining these management decisions, equivalently it could imply that the measure for risk attitudes is not adequately broad or flexible enough to pick up the true characteristics of risk perception or valuation.

A variation on the mean-variance type of model is the value at risk (VaR) approach. In a sense, this method foregoes attempting to measure risk aversion by allowing the user to reformulate the portfolio based upon an acceptable relationship between confidence level and losses. This method, common in financial literature, has garnered some attention in agricultural literature in recent years (Tomek). Applications of this method to risk management by dairy farmers have been used to examine the use of hedging as a means for risk balancing (Zylstra et al.) as well as a means to overall value at risk reduction (Bamba and Maynard). Although these works add to the literature by the application of a novel risk management measurement to agriculture, the measure of value at risk itself is not without its faults. Consistent with its relationship to mean-variance approaches to risk management, the success of value at risk is heavily dependent upon the accurate characterization of the underlying behavior and interrelationships between assets. In addition, value at risk is often criticized for giving a potentially false sense of security as the losses beyond the assumed confidence level could be devastating to the business (Damodaran).

Another disparity between many of these models and real world behavior is the separation of risk management activities from the financial structure and goals of the business (Collins). This is deemed to be a necessary linkage by Collins as one of his four criteria focuses on the effects of capital structure on hedging decisions. This linkage will be examined in greater detail, as it is a primary driver in the development of this work. With respect to consideration of financial structure in the risk management decision process, Collins acknowledges several that do attempt to incorporate this linkage. Specific focus is afforded in his work to those papers published by Turvey and Baker. These models explicitly account for the expected positive relationship between financial leverage and hedge ratios by setting the hedging decision within the greater context of whole farm financial decisions. While these models adequately demonstrate this capital structure and hedging interplay, they are not able to clearly demonstrate the observed relationships between price variability and hedging, nor do they explicitly show the possibility of a no hedge context. Still, these models, as well as others of this nature, played an important role in bringing the hedging decision into a broader business management context (Collins). Bosch and Johnson did just this in their modeling of a Virginia dairy farm. This work examined the effects of hedging feed costs and the use of crop insurance on net farm income (Bosch and Johnson). While this work does an excellent job of fitting the idea of risk management within the financial context of the farm, it does not go so far as to identify and examine any type of causative relationship between the financial situation observed and the chosen risk management strategy as one would expect a hedging decision to be based upon the financial structure and goals of the farm business.

These models represent the major types of models reviewed by Collins and represent a major part of the literature looking to incorporate uncertainty into agricultural models. In addition to providing a general overview of the progression of models in agricultural risk management, Collins also puts forth his own model, positive in nature, of the risk management decision faced by various agents in agriculture. The goal in developing this model was to gain the ability to explain all risk management actions that occur in agriculture. The four conditions of this model were listed earlier in this section. Collins succeeds in meeting these in a concise manner. Terminal equity above some unacceptable level defines the objective as the business is considered a financial entity through which stakeholders can only continue to earn returns if the business survives (Collins). Using terminal equity as the measure of concern, it is then demonstrated how this measure is a function of beginning equity, a random set of prices, debt and interest obligations, output of the firm and associated variable costs, and other fixed costs of the firm. This formulation fulfills all of the previously mentioned conditions. At the same time, using national average figures for farm equity it is demonstrated that five successive years of output prices equal to zero are required before pushing the average farm to insolvency (Collins). While this is a powerful display of the lack of economic incentives for the average farm to engage in hedging, the model parameters are such that some farms, such as those with higher financial leverage, may in fact face incentives to hedge.

In a similar fashion the model developed in this thesis allows the user to observe how various parameters such as price variance or debt to asset ratios may change the outcomes of various risk management strategies thus visually and quantitatively demonstrating the role these parameters may play in creating incentives to manage price risk. This thesis implicitly recognizes hedging and risk management as a subset of operational and strategic management efforts and not as an independent consideration.

Modeling Commodity Price Behavior

The works by Tomek and Peterson provide a good overview of the progression in theory and modeling of commodity price behavior, an integral component in any type of agricultural model incorporating risk. Using their works as a foundation, an understanding of the progress and limitations with respect to modeling commodity price behavior is developed in this section.

While Tomek and Peterson and analyze many different attempts to model commodity prices, their main contention remains that despite these abundant endeavors the best fitting and consistently reliable descriptions of commodity prices are yet to be convincingly demonstrated (Tomek and Peterson 2001, 2005). Causes for this absence of absolute certainty are several including the observed levels of high volatility, autocorrelation and correlated higher moments of these prices (Tomek and Peterson 2001). In addition, one must at the very least acknowledge the possibility that the statistical tools currently used to examine price behavior may be ill suited to the task (Taleb). Implicit in the discussion of price behavior is a concurrent discussion of the validity of the mean-variance, or portfolio, approach to risk management as mentioned earlier. This approach is contingent upon successful estimation of price behavior and relationships between assets. An alternative manner of modeling price behavior is through the use of fractals. According to this view, price behavior is better approximated through power-law distributions as opposed to normal or lognormal distributions, thus nullifying the use of standard deviation as a measure of risk (Damodoran). A multitude of efforts supporting and discounting the idea of commodity prices as patterned, random, or fractal in nature have been made over the last several decades (Mandelbrot; Stevenson and Bear; Turvey and Power). For the purposes of this work, these efforts will be assumed to continue for the foreseeable future as they are directly related to the underlying issue of how incomplete information should be defined and measured. While this deeper debate, as hinted at in the introduction of this section, is not within the scope of this work, recognition of the limitations of our knowledge is necessary in order to provide an honest exploration of the issues that are explored in this work. As will be seen later, Tomek and Peterson themselves recognize our limited ability to characterize price distributions and to create consistently accurate forecasts (Tomek and Peterson 2001, 2005). However, it is still of value to the current discussion of price behavior to recognize the progress and contributions to the literature.

At the elementary level, commodity price behavior is theorized to be composed of structural factors within and across years as well as stochastic impacts, both of which are affected by the information set available at the time. In some sense, all subsequent price behavior research can be seen as further explorations of each of these components. With respect to monthly milk prices, Wang and Tomek provide a good overview of the associated descriptive statistics as well as a structural model used in forecasting monthly milk price. Focused efforts have yielded much research regarding more detailed and complex models of the effects of structural components such as inventories and industry cycles as well as more enhanced descriptions of the correlation and varying levels of volatility within price series (Tomek and Peterson 2001). In their later paper, the various approaches to price modeling are evaluated in the context of providing marketing advice. The general conclusions drawn were that evidence tends to favor an efficient view of futures markets and that econometric forecasting models were not able to consistently generate precise price estimates, nor did marketing services, with presumably superior private information (Tomek and Peterson 2005). This section was not aimed to discount the contributions and efforts of the various attempts at modeling price behavior. Rather, it aimed to on the one hand recognize the typical structure used to model prices while on the other recognizing that concentrating resources in pursuit of a forecasting model which yields output with consistent statistical significance may in fact be diverting energies away from more applied approaches, which may in their own way provide services of economic significance to producers. In assessing the allotment of research resources, emphasis should be placed in areas which should yield the largest marginal benefit. While continued attempts to better characterize prices and basis behavior may prove valuable, many other opportunities exist to assist farmers in framing their decisions, improving knowledge of the true costs of various marketing and investment alternatives, and creating a more pertinent understanding of the risks facing agricultural operations (Tomek and Peterson 2001).

Additional Considerations in Developing this Work

The objectives of this work are influenced by the suggestions for further research provided by Collins, Tomek and Peterson in their works reviewed above. Specifically it looks to provide a financial setting within which a decision maker can evaluate the benefits and costs of various market risk management tools. This is accomplished through the use of simulated commodity futures prices integrated with pro-forma financial statements.

An elementary price model is used to simulate an efficient market, which inherently assumes a random walk of prices. All parameters of this price model, with the exception of the starting date, are able to be adjusted by the user. The price series generated are constrained only by the actual strictures imposed by the commodity futures exchanges. In addition, the user is able to simultaneously examine the results of several risk management tools across varying levels of leverage, volatility and coverage. This parallels the approach suggested by the general positive theory of hedging proposed by Collins.

In addition to the proposals by Collins and Tomek, other motivations and influences on this work are discussed herein. As mentioned earlier, this work does not take the perspective of price variation in isolation representing the idea of risk, but considers price variation as part of the total risk faced by a farm business only when it has a distinct impact on the ability of the business to achieve the goals of stakeholders. One could easily imagine a scenario where prices remain constant however other environmental or economic factors drastically increase the fixed expenses of the business, thus the business faces potential impacts, or risk, even in the absence of volatile prices. This work places the management of price variation within the broader context of operational or strategic management. This approach places price risk management as a means towards achieving other business goals (Johnson and Boehlje).

Recent literature has started to examine risk management in this broader light combining financial, business and strategic considerations as part of the risk management process. The Moorepark Dairy System Model takes a whole-farm approach to modeling uncertainty by including milk production, milk prices and feed prices as stochastic variables (Shalloo et al.). A stochastic budgeting approach has also been used to analyze various farm investment options (Lien). Others, such as the work by Drye and Cropp, have moved beyond the strictly calendar or time-based hedging decision criteria to more selective approaches. Although their work attempted to move towards selective hedging strategies, results did not meet the predicted improvement in cash flow for the farms analyzed (Drye and Cropp). However their selective approach to hedging signals a valuable shift in focus. Although time based, routine, hedging strategies may be easier to model, it is the contention of this thesis that they are not necessarily representative of how producers develop hedging protocols. Drye and Cropp acknowledged several shortcomings in their work including the limitations associated with performing a simulation using historical data, basing hedging entry points on historical distributions rather than calculated farm goals, and not incorporating the actual costs of hedging.

This thesis aims to complement and improve on the extension literature approach of the University of Wisconsin by developing simple marketing triggers based on the current and expected financial situation of the farm (Bernhardt; Bernhardt and Sutter). These marketing triggers will be aimed towards achieving the straightforward business goals of maintaining net worth and meeting cash flow demands (Betz). Thus the financial situation and operating environment of the farm play an integral role in defining price risk management strategies. This work also directs itself toward simultaneous consideration of both milk and feed prices, thus strategies are selective in nature due to being based on business goals and are related to a margin rather than an output or input price considered independently. Finally, costs associated with the simulated risk management strategies, including margin calls, are integrated into this work. Few works incorporate the costs of hedging or other risk management tools, however results from those that have suggest that these costs should be given more consideration in modeling the actual outcomes of risk management strategies (Arias et al.).

The modeling approach in this thesis is Monte Carlo simulation. This approach allows variables within a model to be treated as random by defining the inputs as distributions of potential values. As a result, the key output variables are represented as distributions rather than point estimates. This technique allows for a broader concept of risk to be developed within the model as numerous variables can be treated as probabilistic. In using this technique to simulate daily prices and price series, this model allows for the observation of alternative price paths thus allowing for more equitable judgments regarding the success of a given risk management strategy (Taleb). While this technique adds tremendous value by more completely describing risk, its success is ultimately dependent upon quality inputs, accurately modeled relationships and critical judgments by the decision maker, as is the case with other modeling techniques previously described in this section (Damodaran).

Simulation techniques have been applied in many areas of the agricultural risk management literature. Simulating random shocks and their associated effects on financial statements was done in order to examine investment decisions on a dairy farm (Lien). As mentioned earlier, simulation techniques combined with pro-forma financial statements were used to examine the effectiveness of various hedging strategies for a milk processing cooperative (Manfredo and Richards). Also discussed earlier, simulation techniques were used to link various management strategies, stochastic production and random price levels with farm budgets in order to evaluate the possible success of the management approaches in question (Shalloo et al.). In addition, simulation techniques have been used as a way to enhance learning regarding risk management tools and financial management (Trapp; Klose and Outlaw).

In sum, this thesis contributes to the literature by supplying a flexible framework within which the user may gauge the effects of selective risk management strategies at the whole-farm level in addition to the sensitivities of these effects to changes in market volatility and debt load of the farm. This model structure allows the user to explore not only the cost of hedging but also the timing of these costs and their associated effects on the pro-forma cash flow budget.

CHAPTER III: METHODS

This section provides an overview of the methods used in developing and evaluating the financial statements, simulation models, and other assumptions in this work. All assumptions made were aimed at singling out the effects of milk, corn, and soybean meal price volatility on the financial performance of the farm.

Model Structure

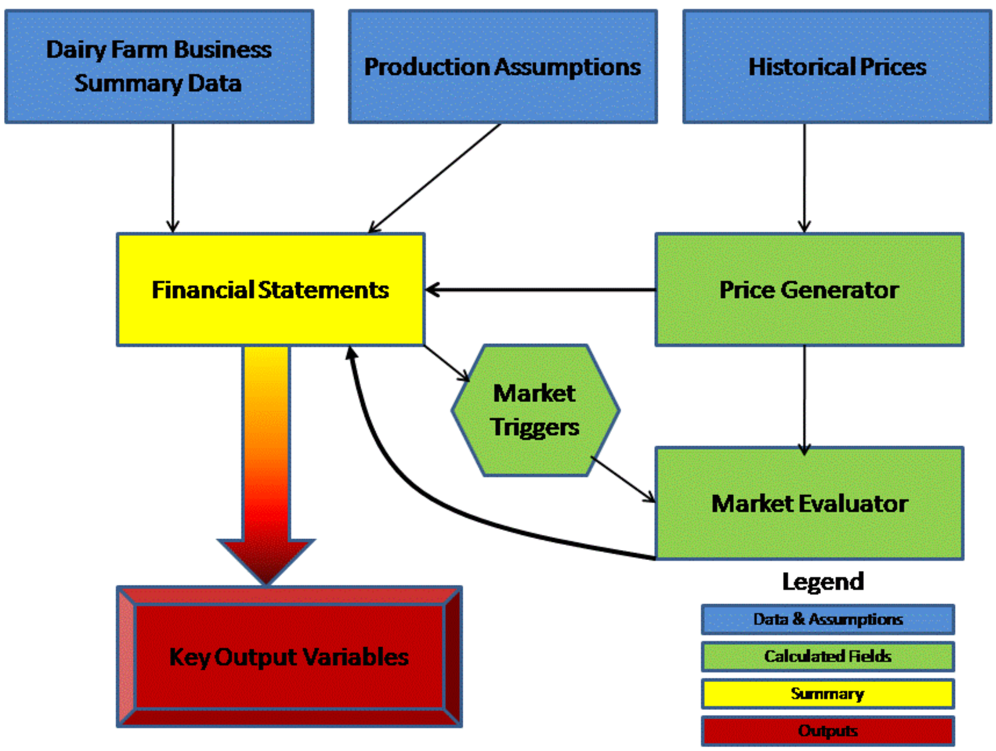

Figure 2. Model Structure and Flow Chart

Development of Financial Statements

This work is grounded in the development of basic financial statements, which serve as a foundation for the development and evaluation of various market risk management strategies. The basic financial statements included in this work are a cash flow budget, beginning balance sheet, income statement, and ending balance sheet. These statements allow for the development of elementary marketing goals grounded in the financial situation of the modeled dairy farm. The marketing goals developed are the maintenance of net worth and the meeting of all cash flow demands during the year. The income over purchased feed cost (IOPFC), or the difference between milk revenues per cow and the combined expense of purchased corn and soybean meal per cow, necessary to meet the marketing goals can then be calculated based upon the assumed ration and financial situation of the dairy farm. The calculated levels of IOPFC required to meet the defined marketing goals are used as triggers, which if simulated market prices meet these triggers the use of a risk management tool will be initiated.

The cash flow budget developed follows the example of the "Dairy Cash Flow" spreadsheet developed by Betz and Robb. For the purposes of this work, several updates were made to this file including a change in the number and names of the operating receipts and expenses categories. This was done in order to simplify the cash flow budget by reducing the number of relevant categories and to better match the categories used in the Dairy Farm Business Summary at Cornell University, which serves as the basis for many of the assumptions used in the development of these financial statements

The cash flow budget was also based on several structural assumptions. All receipts and expenses are calculated on an annual basis and then equally distributed across the year. The only exceptions were the categories treated as random, namely milk receipts as well as corn and soybean meal expenses. Proceeds from milk sales are received in the month following production, for instance the income from December milk production is received in January. In addition, all purchased feeds are received at the start of each month, fed out during that month to a remaining inventory of zero and paid for by the end of the month. Milk production per cow and the number of cows in milk are assumed to be constant throughout the year. Also, the ration fed to the milking herd is assumed to be constant throughout the year. Feed expenses for heifers were estimated using information available in the literature (Karszes, Wickswat, and Vokey). The total number of heifers on the farm was estimated based on average proportions between total cows and heifers shown in the DFBS (Knoblauch). For the sake of simplicity, this work makes the assumption that dry cow feed expenses are two times the expenses of feeding heifers. The number of dry cows was estimated based upon an assumption of eighty-five percent of the total cow herd being in milk at any time of the year. This assumption is based upon the average length of lactation of a dairy cow at 305 days, which is roughly eighty-five percent of the calendar year.

Operating loans are used to cover any cash deficiencies during the year. The operation is assumed to be a sole proprietorship, thus income is taxed at an assumed combined state and federal individual income tax rate of thirty-five percent. These are the basic structural assumptions of the cash flow budget. Other assumptions related to specific categories are described in later sections of this chapter.

Annual receipts and expenses were estimated using data available in the Dairy Farm Business Summary (DFBS) and other extension publications. The DFBS conducted by Cornell University is an annual analysis of various New York dairy farm businesses, which participate voluntarily in the state wide survey (Knoblauch et al.).

The procedures used to estimate category values are described herein. The statewide summary figures from 2005-2007 were used to calculate receipts and expenses on a per cow basis. Specifically, information was gathered from tables forty-nine through fifty-six of the Dairy Farm Business Summary, which summarize the annual data reported based on herd size. For the purposes of this work the largest herd size category, more than 600 cows, was used. Within this category, the average herd size ranged from 1,019 cows in 2007 to 1,078 in 2005. Values in these tables relating to milk production, assets, liabilities, receipts, and expenses were recalculated on a per cow basis by dividing by the average herd size for each year. The standardized values found in this manner were then averaged across the summary years of 2005-07. These average values were then multiplied by 1,000 in order to generate the total amounts used in the modeled 1,000 cow dairy. This method was used for all expense categories along with asset and liability values unless otherwise stated. Tables illustrating these values and calculations are provided in the next chapter.

Structural Assumptions in Developing Financial Statements

More detailed explanations on specific category calculations are given here, beginning with the cash flow budget. In general, the monthly cash flow budget items were determined by evenly dividing the annual totals across the twelve months of the year. The exceptions to this rule were the categories previously defined in this work as random variables as well as the number of milking cows, daily milk per cow, operating line borrowings, and all line items directly related to the use of risk management tools. In addition, the annual totals for all categories excluding hired labor, corn purchases, and soybean meal purchases were condensed into one category titled "other operating expenses". This was done in order to accommodate the assumptions surrounding accounts payable. As mentioned at the beginning of this chapter, all assumptions and the structure of the model are focused towards illuminating the effect on the business of managing price variance. In the case of accounts payable, this work assumes a zero net change in accounts payable. In other words the accounts payable at the end of the year equal the accounts payable at the beginning of the year, therefore the zero net change in accounts payable will have no impact on net income or on the balance sheet. This zero net change was accomplished by first assuming that certain expenses must be met as cash expenses in the month incurred. For purposes of this work hired labor expenses, corn purchases, and soybean meal purchases were assumed to be expenses paid during the month incurred. This assumption was made based on payroll needing to be met as soon as possible following work performed. With respect to corn and soybean meal it was assumed that payment would be made by the end of the month as delivery occurred by the first of each month. The average accounts payable present on the beginning balance sheet was calculated using DFBS information. This value was then subtracted from the "other operating expenses value" described earlier. This difference was then used as the value to divide over the twelve months of the cash flow budget. Thus the accounts payable remains consistent from the beginning of the year to the end. Further descriptions regarding the link between the financial statements and the risk management tool being analyzed are given later in this section.

Development of Balance Sheet

Developed in conjunction with the cash flow budget was the beginning balance sheet. This links the liabilities on the balance sheet with the obligations shown on the cash flow budget. The balance sheet for the modeled dairy was developed based upon the assets. In other words, assets were estimated first and held constant across each of the debt to asset levels analyzed in this work, while liabilities were calculated based upon those associated debt to asset levels. Values for each of the asset categories were determined in a similar fashion to the calculations performed in developing the cash flow budget. Information from the tables in the DFBS previously mentioned was used to calculate asset category values on a per cow basis for summary years 2005 through 2007. These calculated values were then averaged and multiplied by 1,000 in order to reflect total values for the modeled farm. On the liability side of the balance sheet, a similar approach was taken for both the accounts payable and operating line categories.

In contrast, an iterative approach was taken in order to determine the respective levels of intermediate and long term liabilities and their current portions due, based upon an assumed debt to asset level. In order to accomplish this, several assumptions were made. First, the intermediate liabilities were assumed to be held under one seven year loan with four years remaining on this loan. Second, the long term liabilities were assumed to be held under one twenty year loan with fifteen years remaining to maturity. Interest rates were estimated by dividing the interest paid by herds with 600 or more cows by the sum of intermediate and long term liabilities shown on the beginning of year balance sheet in the 2007 DFBS summary tables 55 and 56. It was assumed that operating loan would have a higher interest rate than the intermediate loans, which in turn would have a higher interest rate than the long term obligations., Because interest rates are not explicitly reported in the DFBS, unique interest rates were estimated for operating loans, intermediate loans and long term loans using the Solver add-in for Excel. This was accomplished by first calculating the average interest paid by large farms as reported by the DFBS summary from 2005 to 2007. The assumption was then made that the interest paid on the average beginning of the year values for operating loans, intermediate liabilities, and long term liabilities would account for this total annual interest expense. Thus it could be said that a given annual interest rate times the beginning of year balance would yield a proportional value of the annual interest expense, and the sum of each of these calculated parts should equal the annual expense. The Solver add-in for Microsoft Excel was then used to set the total annual interest expense equal to the average value calculated using the DFBS data by changing the respective interest rates, subject to the constraint regarding the relative magnitudes of the rates mentioned previously. Using this method, the interest rates for operating loans, intermediate loans, and long term loans were 6.74%, 7.24%, and 8% respectively. For purposes of this thesis, these figures were rounded to the nearest quarter percent. Interest on the outstanding balances of the previous year operating loan and current year operating loan is calculated on a daily basis. Interest on intermediate and long term liabilities is calculated on a monthly basis.

Amortization tables were then developed for each of these loans assuming that equal payments were made on each loan on a monthly basis. Similar to the methods used to determine interest rates, a table was constructed for purposes of determining the exact portions of current, intermediate, and long term obligations of these loans necessary to meet the desired debt to asset ratio when combined with the accounts payable and beginning operating line, which were assumed to be constant regardless of the debt structure of the farm. The current principal and interest due on the balance sheet were linked to the associated payment periods in the amortization tables for each loan. In addition, a ratio was set up between the intermediate liabilities and long term liabilities in order to maintain the average proportion between these categories as shown in the DFBS table 55. The Solver application in Microsoft Excel was then used to set the debt to asset ratio cell to the desired level by simultaneously adjusting the beginning loan amounts for both intermediate and long term liabilities subject to the constraint that the ratio between the intermediate and long term liabilities on the balance sheet must maintain the previously mentioned ratio between these categories. This information was then used to complete the balance sheet for each modeled debt to asset ratio.

Completion of Cash Flow Budget

Once the assumptions and calculations were made for the beginning balance sheet the cash flow budget could be completed. Cash for capital purchases such as dairy cow replacements was estimated in a similar fashion to other expense categories. Capital purchases for machinery or building improvements were set equivalent to the estimated depreciation values for each of these categories. This was done in order to discount the effect of depreciation on the asset values of machinery and buildings thus keeping these depreciable asset values constant from the beginning to the end of the year. Gross family living withdrawals were estimated in the same way as other expense category, however, the data used to calculate the average value came from table fourteen of the DFBS, which includes information from all herd sizes. No attempt was made to adjust this estimate to better reflect a larger herd size. Income and social security taxes were estimated by averaging the net farm income, on a per cow basis, reported in table fifty-five of the DFBS and multiplying this times the number of cows in the model and by the assumed total tax rate. Income tax due was treated as a liability on the beginning balance sheet. For the sake of simplicity, the previous year tax obligation is assumed to be paid out in equal monthly payments over the current operating year. With respect to planned debt payments, monthly principal and interest amounts were taken directly from the amortization tables for both intermediate and long term liabilities.

The components of the financial statements discussed thus far represent the basic considerations made before the effects of various risk management tools and short term borrowing. Each risk management tool, such as futures contracts or options, will have different categorical costs associated with it, such as margin calls for futures contracts and premium payments for options. Thus, each risk management strategy is analyzed independently in this work by using a unique set of coordinated financial statements for each. Expenses and payoffs associated with the risk management tool chosen are found within the other expenditures area of the cash flow budget associated with that tool. While the exact categories differ among the tools, the cash flow budget for each tool accounts for the total cost associated with using the tool and the payoff, if any. Descriptions regarding specific expenses and calculations associated with each tool are available later in this section when each of those tools is individually detailed.

All pieces required to calculate the cash position, before borrowing, have now been enumerated. If a shortfall occurs, this model assumes the cash obligation must be met through the use of a revolving operating loan. For the sake of simplicity, the operating lines of credit were modeled without a set limit and within the model used to meet both operating expenses as well as risk management costs. The total amount borrowed in each month is contingent upon two joint factors. First if a cash shortfall arises, the amount necessary to bring the cash account back to zero is borrowed. In addition, if the cash position, before borrowing, less all principal and interest payments is less than one dollar then an amount equal to all principal and interest payments plus an assumed additional amount of $20,000 is borrowed. This additional amount is borrowed in order to provide a small cushion against unforeseen expenses each month.

The amount of the current operating loan paid back each month is dependent upon several pieces of information. First, in order to make a payment on the current operating loan in the current month, the previous month must have a positive amount in the current operating loan balance category. If this condition is met, then a second condition is imposed, which requires that the cash position, before borrowing, less the monthly principal and interest on the previous year operating loan and interest payment on the current operating loan is greater than zero. If this second condition is met, then the minimum of either the full outstanding balance on the current year operating loan is paid or the difference between the cash position before borrowing less the principal and interest payments on the previous year operation loan and interest on the current year operating loan outstanding balance is paid. If the second condition is not met, then no principal payment is made on the current year operating loan. Following all of these categories and calculations the ending cash balance is calculated, this then becomes the beginning cash balance for the following month. The following figure serves as an example of the cash flow budget.

Figure 2. Cash Flow Budget

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1														Ending Cash Balance-->		$310,477
2	CASH FLOW BUDGET for			Farm Name	Thesis Acres				Dairy Farm Cash Flow Budget					Ending Operating Loan------>		$0
3	Thesis Acres			Address												
4	Date Completed															Amount to
5		January 1	January	February	March	April	May	June	July	August	September	October	November	December	12 month	Allocate 1/12th
6		Beginning Cash Balance	46,236	$49,477	$17,425	$20,000	$47,618	$76,420	$7,501	$70,511	$261,700	$239,348	$310,698	$275,672	Totals	per Month
7	December	**Operating Receipts:**														
8	1,000	Milking cows	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000.0	Ave Cows
9	80	lbs milk sold per cow per day	80	80	80	80	80	80	80	80	80	80	80	80	80.0	Milk /cow/day
10	2,480,000	Total lbs milk sold per month	2,480,000	2,240,000	2,480,000	2,400,000	2,480,000	2,400,000	2,480,000	2,480,000	2,400,000	2,480,000	2,400,000	2,480,000	292,000	Total CWT Sold
11	17.00	Expected milk price per 100 wt	$13.70	$13.51	$14.65	$15.35	$16.79	$17.73	$21.36	$12.61	$17.60	$12.47	$15.87	$11.79	$15.73	Average Price/CWT
12		MILK INCOME 1mth Delayed	$421,600	$339,806	$302,730	$363,204	$368,337	$416,304	$425,544	$529,714	$312,843	$422,408	$309,278	$380,814	$4,592,582	
13																
14		DAIRY CALVES	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$4,755	$57,062	$57,062
15		Other	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$12,351	$148,206	$148,206
16	Capital Receipts:															
17		Cull Cows	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$22,299	$267,586	$267,586
18	**TOTAL CASH AVAILABLE**		**$507,241**	**$428,687**	**$359,559**	**$422,609**	**$455,360**	**$532,129**	**$472,450**	**$639,629**	**$613,947**	**$701,160**	**$659,380**	**$695,890**	**$5,375,914**	
19																
20	Operating Expenses:															
21		Hired Labor	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$58,845	$706,145	$706,145
22		Purchased Dairy Grain and Concentrate-Corn	$33,946	$31,052	$32,842	$60,390	$63,065	$45,190	$47,549	$33,404	$30,266	$38,495	$37,939	$39,422	$493,568	
23		Purchased Dairy Grain and Concentrate-SBM	$6,611	$6,351	$6,995	$8,019	$8,585	$13,799	$15,515	$5,612	$5,673	$10,368	$7,304	$7,620	$102,453	Accrual less AP
24		Other Operating Expenses	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$197,434	$2,369,213	$2,369,213
25	**Total Cash Operating Expense**		**$296,837**	**$293,683**	**$296,116**	**$324,696**	**$327,950**	**$315,269**	**$319,344**	**$295,296**	**$292,220**	**$305,142**	**$301,523**	**$303,322**	**$3,671,398**	**$3,075,358**
26																
27	Other Operating Expenses															
28		DAIRY PURCHASE	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$1,811	$21,734	$21,734
29	Capital Expenditures:															
30		MACHPURCH	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$15,317	$183,808	$183,808
31		IMPRPURCH	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$10,245	$122,936	$ 122,936
32																
33	Other Expenditures:															
34		Hedging account deposits -Milk	$ 48,000	$12,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$60,000	
35		Hedging account deposits-Corn	$12,140	$3,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,140	
36		Hedging account deposits-SBM	$8,000	$2,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000	
37		Margin Calls-Milk	$2,297	$11,218	$0	$0	$3,038	$10,188	$0	$0	$0	$3,028	$0	$0	$29,769	
38	Risk Mgmt. Strategy Info.	Margin Calls-Corn	$5,023	$1,254	$1,221	$3,118	$775	$0	$0	$0	$0	$0	$0	$0	$11,392	
39		Margin Calls-SBM	$2,268	$5,116	$2,792	$0	$0	$0	$0	$140	$0	$0	$0	$0	$10,317	
40		Hedging Account Ending Less Broker Fees-Milk		$0	$0	$0	$0	$14,565	$11,774	$36,159	$0	$25,762	$0	$42,716		
41		Hedging Account Ending Less Broker Fees-Corn		$0	$0	$0	$11,561	$6,553	$7,401	$0	$2,860	$0	$9,764	$0		
42		Hedging Account Ending Less Broker Fees-SBM		$0	$0	$0	$4,104	$6,351	$11,566	$0	$2,082	$0	$5,623	$0		
43		Gross family living withdrawals	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$7,009	$84,113	$84,113
44		Income tax and social security	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$17,451	$209,418	$209,418
45																
46	Intermediate Liabilities - Principal		$9,208	$9,264	$9,320	$9,376	$9,433	$9,490	$9,547	$9,605	$9,663	$9,721	$9,780	$9,839	$114,246	
47	Intermediate Liabilities - Interest		$3,087	$3,032	$2,976	$2,919	$2,863	$2,806	$2,748	$2,691	$2,633	$2,574	$2,515	$2,456	$33,299	
48	Long Term Liabilities - Principal		$1,110	$1,116	$1,123	$1,129	$1,135	$1,142	$1,148	$1,155	$1,161	$1,168	$1,174	$1,181	$13,743	
49	Long Term Liabilities - Interest		$1,937	$1,931	$1,924	$1,918	$1,912	$1,905	$1,899	$1,893	$1,886	$1,880	$1,873	$1,866	$22,824	
50	**TOTAL CASH REQUIRED**		$441,743	$395,449	$367,307	$394,991	$398,940	$392,633	$386,521	$362,613	$359,396	$375,347	$368,700	$370,499		
51																
52	Cash Position before Borrowing		$65,498	$33,238	($7,748)	$27,618	$56,420	$139,496	$85,929	$277,017	$254,551	$325,813	$290,680	$325,391		
53																
54	Money to be borrowed:															
55		- operating loans borrowed	$0	$0	$43,568	$47,618	$76,420	$0	$0	$0	$0	$0	$0	$0	$167,606	
56																
57	Operating loan payments:															
58		Current year's - principal	$0	$0	$0	$11,632	$40,261	$115,713	$0	$0	$0	$0	$0	$0	$167,606	
59		Previous year's - principal	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$14,814	$177,763	$177,763
60		Annual interest rate- Operating Loans	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%		
61		Interest on Prev. Year Operating Loan Balance	$1,208	$1,000	$1,007	$877	$805	$682	$604	$503	$390	$302	$195	$101	$7,672	
62		Interest on Curr. Year Operating Loan Balance	$0	$0	$0	$296	$541	$786	$0	$0	$0	$0	$0	$0	$1,623	
63	Ending cash balance		**$49,477**	**$17,425**	**$20,000**	**$47,618**	**$76,420**	**$7,501**	**$70,511**	**$261,700**	**$239,348**	**$310,698**	**$275,672**	**$310,477**	**$310,477**	
64																
65	Loan Balances: (at end of period):															
66		Current year's operating loans														
67		$0	**$0**	**$0**	**$43,568**	**$79,554**	**$115,713**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**		
68		Previous year's operating loans:														
69		$177,763	$162,949	$148,135	$133,322	$118,508	$103,695	$88,881	$74,068	$59,254	$44,441	$29,627	$14,814	$0		
70		Intermediate Liabilities:														
71		$510,983	501,775	492,511	483,191	473,815	464,382	454,892	445,345	435,740	426,077	416,356	406,576	396,737		
72		Long Term Liabilities														
73		$344,357	343,247	342,130	341,007	339,878	338,743	337,601	336,453	335,298	334,137	332,969	331,795	330,614		
74	Consistency Check:															
75		Total inflows incl. borr. money	$507,241	$428,687	$403,127	$470,227	$531,780	$532,129	$472,450	$639,629	$613,947	$701,160	$659,380	$695,890		
76		Total outflows	$457,764	$411,262	$383,127	$422,313	$454,819	$523,842	$401,939	$377,930	$374,600	$390,462	$383,708	$385,413		
77		Budgeting error	$49,477	$17,425	$20,000	$47,914	$76,961	$8,287	$70,511	$261,700	$239,348	$310,698	$275,672	$310,477		
78																

Completion of Income Statement and Ending Balance Sheet

The main driver behind all assumptions made in the development of the model and the financial statements was to highlight the effects of price risk management. In this light, the income statement represents a simplified version of the typical accrual based farm income statement. As such, the changes in inventory were assumed to be zero. While this may not be a realistic assumption it is not altogether unreasonable as inventory changes are a rather small percentage of accrual expenses in the DFBS income statement. Accounts receivable are determined solely by revenues associated with milk production including any effects due to associated risk management tools such as futures account withdrawals. As discussed earlier within the context of the cash flow budget, accounts payable calculations were structured in order to show no net change. Thus the major determinants of annual accrual revenues and expenses are the cash receipts and expenditures. The total for cash receipts is determined by the sum of milk, dairy calves, cull cows, and other receipts. The total for cash expenditures is determined by the sum of operating expenses, dairy cow purchases, interest expenses, and taxes. Depreciation expenses for machinery and improvements were estimated in a similar fashion to other expense categories. These categories yield the net farm income before taxes. Multiplying this amount by the assumed tax rate gives the tax amount due during the following year, which appears on the ending balance sheet. Subtracting the tax amount owed from the net farm income before taxes figure then yields the final net income.

Following completion of the income statement the ending balance sheet is constructed in order to show the ending equity of the owner. The ending cash balance and accounts receivable figures are sourced from the cash flow budget. As discussed earlier, the model assumes no change in inventories or livestock values thus these values are equivalent to their beginning balance sheet values as are the other stocks and investments. Ending values for machinery and equipment and real estate are equal to beginning values due to the offsetting figures for depreciation and capital investment. On the liabilities side, ending accounts payable are equal to the beginning value due to the calculations made in the cash flow budget. The ending liabilities associated with current portions and interest of intermediate and long term obligations are taken from the amortization tables. These figures represent the summed obligations due in the next twelve months, starting after the last month referenced in the beginning balance sheet calculations for these liabilities. As mentioned in discussion relating to the income statement, the income tax liability is calculated based on the current year net farm income before taxes is to be paid over the upcoming business year. Like the current portions, the remaining balances of the intermediate and long term liabilities are taken directly from the amortization tables. These ending asset and liability values are then used to determine ending owner equity along with the percent change in owner equity, which are key output variables of the model. Finally, these pro-forma financial statements are used to construct marketing triggers that in turn help to determine actions to manage market price risk. An example of the income statement and balance sheet is shown below.

Figure 3. Income Statement and Balance Sheet

	A	B	C	D	E	F	G	H	I	J	K
1	**Beginning Balance Sheet**			**Income Statement**						**Ending Balance Sheet**	
2	Current Farm Assets				Cash Receipts	Change in Inventory	Change in Accounts Receivable	Accrual Receipts		Current Farm Assets	
3	Farm cash	$ 45,774		Operating Receipts	$4,895,288	0	$ (67,738)	$4,827,550		Farm cash	$239,755
4	Accounts Receivable	$ 421,600								Accounts Receivable	$ 304,086
5	Feed and Supplies	$ 715,210			Cash Expenditures	Change in Inventory	Change in Accounts Payable	Accrual Expenses		Feed and Supplies	$ 715,210
6	Intermediate			Operating Expenses	$3,927,974	0	$0.00	$3,927,974		Intermediate	
7	Livestock	$ 2,011,116		Machinery Depreciation				$ 183,808		Livestock	$ 2,011,116
8	Machinery and Equipment	$ 1,120,988		Building Depreciation				$ 122,936		Machinery and Equipment	$ 1,120,988
9	Other Stock and Certificates	$ 188,516		Total Operating Expenses				$4,234,718		Other Stock and Certificates	$ 188,516
10	Long Term									Long Term	
11	Land and Buildings	$ 2,666,325					Net Farm Income w/out App. Before Taxes	$592,831		Land and Buildings	$ 2,666,325
12							Taxes	$207,491			
13	Total Farm Assets	$ 7,169,530								Total Farm Assets	$7,245,998
14							Net Income	$385,340			
15	Current Liabilities									Current Liabilities	
16	Accounts Payable	$ 135,262								Accounts Payable	$135,262
17	Operating Debt	$ 177,763								Operating Debt	$0
18	Current Portion-Int.	$114,246								Current Portion-Int.	$122,810
19	Current Portion-Long	$13,743								Current Portion-Long	$14,700
20	Accrued Interest-Int.	$33,299								Accrued Interest-Int.	$24,736
21	Accrued Interest-Long	$22,824								Accrued Interest-Long	$21,867
22	Income Tax	$ 209,418								Income Tax	$207,491
23	Intermediate Liabilities									Intermediate Liabilities	
24	Int. Less Curr. Port.	$396,737								Int. Less Curr. Port.	$273,927
25	Long Term Liabilities									Long Term Liabilities	
26	L.T. Less Curr Port.	$330,614								L.T. Less Curr Port.	$315,914
27	Total Farm Liabilities	$ 1,433,906								Total Farm Liabilities	$1,116,707
28											
29	Total Owner Equity	$ 5,735,624								Total Owner Equity	$6,129,291
30										% Change Equity	7%
31											

Development of Marketing Triggers

One of the ways in which this work aims to make a unique contribution to the literature is by explicitly considering selective, as opposed to routine or time dependent, approaches to managing market price risk. A selective approach or strategy, as considered in this work, is defined as some goal which determines the market conditions under which a specific action will be taken (Bernhardt and Sutter). Developing selective strategies and analyzing their results may provide valuable insights on how to better approach market risk management. These strategies, it can be argued, more accurately reflect the thought process of the decision maker with respect to managing price variations. In essence these strategies mark the bridge between managing price variation simply to reduce variation and managing price variation in order to accomplish some operational or strategic goal. Although many such goals could be developed, such as achieving a desired return on assets, this work simplifies the matter by using two primary goals. These goals are to maintain the equity position of the owner and to meet cash flow demands.

As discussed in the literature review, much of the previous academic and extension literature regarding risk management on dairies has been segmented in nature, focusing on only milk price, feed price, or crop yields. In contrast this work offers an integrated approach towards managing price risk by considering both milk price and purchased feed costs. In order to do so a measure is needed that links prices to revenues and expenses experienced by the operation. Income over feed cost does this by using the expected milk production per cow, milk price, ration design, and feed prices to calculate the margin between milk revenues and feed expenses on a per cow basis (Bailey and Ishler). This work adjusts income over feed cost slightly by considering only the purchased feed items, namely corn and soybean meal, in calculating the feed expense. As a result, the measure used may be more accurately referred to as the income over purchased feed costs per cow. Hence, the manager is now looking for a combination of market prices that will yield the desired margin per cow needed to achieve the stated goals. This is in direct contrast to searching for attractive price levels independently for each commodity, as a marketing plan.

The margin is calculated by multiplying the daily production per cow times the milk price then subtracting the total purchased feed cost, which is the summed products of the daily amount of corn fed per cow times the corn price and the daily amount of soybean meal fed per cow times the soybean meal price. This is shown below in the following equation.

$$\text{Income Over Purchased Feed Cost} = P_m Q_m - P_c Q_c - P_s Q_s$$

Where:

P_m = Price of milk (dollars per hundredweight)
Q_m = Quantity of milk per cow (hundredweights per cow per day)
P_c= Price of corn (dollars per bushel)
P_s = Price of soybean meal (dollars per ton)
Q_c = Bushels of corn per cow per day
Q_s = Tons of soybean meal per cow per day

This work assumes that a dairy manager or owner will strive to meet the simple goals of meeting cash flow demands. The desire to meet this goal is a reasonable assumption as it translates to meeting all debt obligations thus helping to ensure the survival of the business. This primary goal is assumed in order to avoid projecting anything more than basic risk tolerance and utility assumptions on the decision maker. Using the pro-forma financial statements, the margin per cow can be calculated for this goal. It is assumed that an owner would use the margin as a trigger or guideline, which signals when the use of a risk management tools appears favorable.

The margin for maintaining net worth, is calculated by summing all operating expenses, less corn and soybean meal expenses as these are assumed to be stochastic, total interest planned payments, depreciation expense, income tax expenses to be paid during the year, and family living and other withdrawals. The resulting figure is then divided by the average number of cows assumed in the model to give an annual margin per cow, which is then divided by the number of operating days in the year, 365, which gives the desired output of income over purchased feed cost per cow per day. The goal of meeting expected cash flow demands is calculated in a similar fashion. Using the total margin needed to maintain net worth as discussed above, before dividing by the average number of cows, calculated for the first goal, depreciation and interest expenses are taken out while scheduled principal and interest payments are added back in as is the total cash needed for capital replacement. Again, this figure is then divided by the average number of cows and number of operating days in the year to yield a daily per cow margin necessary to meet the cash flow demands. A manager can now look at these margins as signals for making a marketing or price management decision, knowing that they are determined by the current financial situation of the operation. These margins are used as triggers and reference values in the price generator and in the subsequent evaluation of the various risk management tools considered in this work. The table on the following page illustrates the calculations just discussed.

Table 1. Marketing Strategy Trigger Calculations

Calculation Fields	Marketing Triggers: Low Debt	Average Debt	High Debt
Total Operating Expenses (Less Corn and Soybean Meal Expenses)	$3,555,496	$3,555,496	$3,555,496
+ Total Interest to be Paid on Intermediate and Long Term Liabilities	$56,124	$126,759	$276,856
+ Depreciation	$306,745	$306,745	$306,745
+ Income Taxes	$209,418	$209,418	$209,418
+ Family Living & Other Draws	$84,113	$84,113	$84,113
"Maintain Net Worth - Income over Purchased Feed Cost"	$4,211,895	$4,282,530	$4,432,628
"Maintain Net Worth - Income over Purchased Feed Cost" per Cow per year	$4,212	$4,283	$4,433
per Cow / day	**$11.54**	**$11.73**	**$12.14**
"Maintain Net Worth - Income over Purchased Feed Cost"	$4,211,895	$4,282,530	$4,432,628
- Depreciation	$306,745	$306,745	$306,745
- Interest	$56,124	$126,759	$276,856
+ Scheduled Principal and Interest Payments	$184,113	$415,830	$908,224
+ Cash Required for Capital Replacement	$306,745	$306,745	$306,745
"Meet Cash Flow Demands - Income Over Purchased Feed Cost"	$4,339,884	$4,571,601	$5,063,995
"Meet Cash Flow Demands - Income over Purchased Feed Cost" per Cow per year	$4,340	$4,572	$5,064
per Cow / day	**$11.89**	**$12.52**	**$13.87**

Development of the Price Generator

As stated in the introduction, this work does not aim to present a cutting edge approach to price modeling, but rather seeks to offer a reasonable and inclusive demonstration of possible price series in order to better understand how various market conditions may alter the process behind managing price risk. With this in mind, price series are generated for each commodity treated as a random variable in the model. The process was straightforward for Class III milk as there are contracts available for each month of the year. However corn and soybean meal have only five and eight associated contracts each year respectively (www.cmegroup.com). Due to the number of feed contracts available, a dairy manager must reference the same contract for more than one month. For example the March contract is used as a reference for both February and March feed pricing conditions. The process for referencing feed contracts is discussed in greater detail following description of the price series. Although some contracts are used as references for more than one month, only one price series is associated with each contract. There are twelve milk contract price series, five corn, and seven soybean meal contracts. It was assumed that January feed was already purchased based on assumed cash prices. The number of days generated for each contract is determined by the number of trading days left on that contract as of the beginning of the year. For the purposes of this work, the trading calendar for 2009 was used to match up calendar dates with trading days and closing days on each contract. For this work, January 2, 2009 is considered is to be trading day one with a total of two hundred fifty two trading days in the calendar year (www.cmegroup.com).

Prices were generated on a daily basis for each contract. The structure supporting this process is the lognormal model of stock prices as is commonly seen in financial literature. This structure is as follows:

$$S_t = S_0 e(\mu - .5\mu^2)t + \sigma\sqrt{t}\,Z$$

Where:

S_0 = Previous stock price
St = Current stock price
μ = Instantaneous return
σ = Annual volatility
t = time frame based on total trading days (i.e. 1/total trading days is one day)
Z = Normal (0, 1) random variable

The appropriateness of a stock price model as a proxy for commodity price behavior is debatable. However it is not necessarily unsound as this structure provides a method to observe the effects of volatility and random shocks on the price series. These random shocks, generated by the @Risk add-in for Excel, create a random walk type of price series through which the effectiveness of risk management tools can be gauged (Winston). Utilizing the lognormal stock price formula allows for straightforward modification of the main parameters of the price series.

Price information from 2003 to 2008 was used in order to estimate price distributions and volatility parameters for class III milk, corn, and soybean meal futures contracts. The simulation model is structured to randomly pick a starting price from an estimated distribution as the starting price for each price series. Thus all iterations of the simulation begin with a random starting price. This allows for greater variability in the nature of the price series as would be experienced in an actual market. Distributions for the starting prices of each commodity contract were estimated using daily closing prices for each commodity. Closing prices were aggregated by contract month. Thus this model assumes consistent market structures among similar contract months between all market years observed. Using the BestFit tool within the @Risk add-in for Excel, the aggregated daily closing prices for each contract month were used to estimate distribution parameters. Distribution fits were ranked using a Chi-Square goodness of fit test. The distribution with the closest fit to the aggregated data was then used to generate the initial starting price. Distributions for each commodity contract month are listed in the following table.

Table 2. Commodity Contracts Fitted Distributions

Commodity	Month	@Risk Distribution Function	Chi Square
Class III Milk	1	RiskLoglogistic(8.2319,3.8996,5.4661)	1,263.28
	2	RiskLoglogistic(8.0513,4.0044,5.5357)	989.98
	3	RiskLoglogistic(7.7732,4.3069,5.2487)	938.57
	4	RiskInvgauss(5.2234,48.6003,RiskShift(7.2312))	1,505.44
	5	RiskLoglogistic(8.3389,3.918,4.1266)	1,228.41
	6	RiskLoglogistic(8.6222,3.9061,3.9195)	729.73
	7	RiskLoglogistic(8.4345,4.5382,4.5926)	758.62
	8	RiskLoglogistic(8.1731,5.0884,5.0571)	661.02
	9	RiskLoglogistic(8.5463,5.0115,4.9525)	759.32
	10	RiskLoglogistic(9.1013,4.1273,4.3964)	708.16
	11	RiskLoglogistic(7.4247,5.4767,5.7701)	1,106.81
	12	RiskLoglogistic(8.1534,4.4963,4.6599)	1,539.47
Corn	3	RiskLoglogistic(1.87866,0.70078,2.8082)	1,187.26
	5	RiskPearson5(4.2791,3.7012,RiskShift(1.6954))	972.66
	7	RiskPearson5(3.1727,2.1793,RiskShift(1.9029))	1,305.76
	9	RiskInvgauss(1.108,1.481,RiskShift(1.9071))	888.54
	12	RiskLoglogistic(1.83402,0.79189,2.8479)	2,739.06
Soybean Meal	3	RiskBetaGeneral(1.7238,13.08,144,553.74)	136.25
	5	RiskPearson5(5.357,335.61,RiskShift(118.31))	122.39
	7	RiskInvgauss(73.106,127.52,RiskShift(135.184))	210.86
	8	RiskInvgauss(73.826,130.747,RiskShift(136.431))	180.75
	9	RiskInvgauss(70.626,123.907,RiskShift(137.009))	253.64
	10	RiskInvgauss(63.352,96.731,RiskShift(138.098))	288.07
	12	RiskInvgauss(63.182,87.481,RiskShift(139.038))	360.47

The annualized rate of return was assumed to be 0 in order to avoid biasing the average trend of the price series. The annualized volatility was estimated by calculating the standard deviation, across the entire life of each commodity contract, of the lognormal daily returns. This figure was then multiplied by the square root of the number of trading days thus yielding the annualized volatility (Hull; Winston).

The price series generated using the estimated parameters mentioned above were filtered so that daily price changes did not exceed the limits set by the commodity exchanges. Specifically, the filter eliminated price changes in the raw series greater than the limit moves by substituting the limit move value, otherwise the generated price change was used. While the major commodity exchanges adjust the limit moves at different points during the life of the contract, a constant limit was deemed a suitable assumption for the purposes of this work. In essence, this structure, its parameters, and filters generate a futures market price series whose price changes are limited as they are in the real world.

The setting of this model is of a dairy manager who develops marketing triggers at the beginning of the year based on the financial structure and goals of the dairy farm business and uses these triggers to make risk management decisions for the duration of the coming year. All corn and soybean meal purchases are made on or near the first of each month, and it is assumed these purchase have already been made for the month of January thus no risk management tools are used for this month. In order to avoid any speculative position in managing price risk, the owner is assumed to use the forward nearby contracts in managing their feed prices and each position is closed out on the same day that transactions are made on the cash market. However there does remain a slight speculative aspect to the corn and soybean meal hedging as the specified contract sizes are greater than the feed requirements on the farm. As an example, in evaluating the margins for February a manager would refer to the March corn and soybean meal futures contracts and the February milk futures contract. The corn and soybean meal positions would be closed out on the first of February when cash market transactions take place. The February milk contract would not be closed out until the expiration date of the contract in early March, as this corresponds to the announcement of the cash price for Class III milk which represents a primary determinant of the final farm price received by the farmer.

With these assumptions, the dairy manager will observe two types of margins in the market. The first type will be generated by futures prices on both milk and feed commodities, and will be observed up until the date when feed must be purchased. Following this date, the margins observed will be calculated using futures prices for milk and known cash prices paid for corn and soybean meal. Margins are generated for each trading day in each month up to the ending trading day in that calendar month. As an example, margins are generated for the month of January up to trading day nineteen while margins are generated for the month of February up to trading day thirty-eight. All margins calculated in the price generator use an assumed constant basis, added to the daily futures prices of the commodities, as a proxy for the expected cash price. Values for the basis of each commodity were assumed due to lack of available information on the relationship between local cash prices and corresponding futures prices. Assumed basis values for the purposes of this thesis can be considered irrelevant because the risk management tools are compared based on their relative effectiveness. While the effects of assuming certain basis values does have an effect on the final net farm income calculations, the structure of the model allows for the basis values to be changed or even to be treated as a random variable. Thus, decision makers with information regarding the basis values they face would be able to use this information to better personalize the results of the model.

A secondary table is constructed within the price generator worksheet which matches the dimensions of the calculated margin matrix. The table reflects whether or not the margins calculated using the generated prices meet either of the predetermined margin levels needed to trigger a marketing action. For instance, if the margin calculated for February, on trading day fifteen, is greater than the margin needed for meeting cash flow demands, a “2” is placed in the matching coordinates of the marketing signals table. If the same calculated margin is greater than the margin needed to maintain net worth, but less than the margin needed to meet cash flow demands, a “1” is placed in the corresponding cell. If the calculated margin offered by the market on that day is less than the required margin associated with either goal then a “0” is placed in the cell, thus signaling that no action should be taken. This table is then the primary link between market observations and the corresponding actions to be taken, which are signaled to the producer. Therefore, analysis of each risk management tool is dependent on this table as it provides information regarding what goal margin, if any, is met given current market conditions, what trading day this margin appears on, and the associated price levels of each of the commodities. These links are discussed in greater detail in the next section.

Development of Risk Management Tool Evaluators

This section details the structure, formulas, and links to the associated financial statements for each of the risk management tools analyzed in this work. The tools for market risk management expressly considered in this work include cash marketing, futures contracts, options and various combinations thereof.

The cash marketing approach is considered the baseline approach for this work. Although some might consider complete cash marketing a “no action” risk management approach, it still represents a conscious choice by the manager which implies acceptance rather than transfer of market risk. The majority of the structural pieces and relationships for the cash marketing approach have already been enumerated in previous parts of this chapter. In order to reiterate the relationship between the price generator and the cash flow budget and other statements, the cash prices or farm level prices are determined by adding a constant basis to the futures price that corresponds to the closing day on each contract. For feed prices, this day is the first or nearest to first trading day of each month and for milk this is the contract expiration day. An example of the evaluator worksheet discussed in the following sections is shown here.

Figure 4. Evaluator Worksheet Example

	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA
1			# Contracts	12			R-F Rate	Volatility	Strike Price			# Options	24
2	**April**						5%	0.10266336	16		Ending Account	Hedging	Beginning Premium
3	IOPFC NW Trigger-Jan.	Trigger-Day	Milk Price	Price Change	Position Profit / Loss	Account	Margin Call	Duration	Premium			26112.18	$ 17,280
4	2	1	15.894685			12000	0	82	0.36		Sum of Margin Calls	5577.367	Options Payoff
5	0	2	15.783979	0.110705199	2656.924776	14656.9	0	81	0.42		# Margin Calls	5	$ 22,125
6	0	3	15.711226	0.072753967	1746.095217	16403	0	80	0.47				
7	0	4	15.679788	0.031437209	754.4930114	17157.5	0	79	0.49		Net Gain / Loss per cwt.	0.355617	
8	0	5	15.609439	0.07034916	1688.379838	18845.9	0	78	0.53				
9	0	6	15.51635	0.093088923	2234.134161	21080	0	77	0.59		Margin Calls by Month		
10	0	7	15.464375	0.051975351	1247.408418	22327.4	0	76	0.63		January	0	
11	0	8	15.23829	0.226084793	5426.035038	27753.5	0	75	0.81		February	5577.367	
12	0	9	15.340465	-0.10217443	-2452.186272	25301.3	0	74	0.72		March	0	
13	0	10	15.411553	-0.07108829	-1706.119013	23595.2	0	73	0.67		April	0	
14	0	11	15.305767	0.105785306	2538.847338	26134	0	72	0.75		May	0	
15	0	12	15.43191	-0.12614232	-3027.415652	23106.6	0	71	0.65		June	0	
16	0	13	15.450717	-0.01880761	-451.382645	22655.2	0	70	0.63		July	0	
17	0	14	15.528559	-0.0778416	-1868.198343	20787	0	69	0.57		August	0	
18	0	15	15.490991	0.037567906	901.6297547	21688.6	0	68	0.6		September	0	
19	0	16	15.355459	0.135531889	3252.765336	24941.4	0	67	0.7		October	0	
20	0	17	15.588912	-0.23345297	-5602.87137	19338.5	0	66	0.52		November	0	
21	0	18	15.724036	-0.13512415	-3242.9795	16095.6	0	65	0.43		December	0	
22	0	19	15.568069	0.155967272	3743.214537	19838.8	0	64	0.54				
23	0	20	15.640529	-0.07245984	-1739.036091	18099.7	0	63	0.48		Account Deposits by Month		
24	0	21	15.827009	-0.18647995	-4475.518798	13624.2	0	62	0.36		January	12000	
25	0	22	15.911518	-0.08450918	-2028.220245	11596	404.0005	61	0.31		February	0	
26	0	23	15.95805	-0.04653214	-1116.77127	10883.2	1116.7713	60	0.29		March	0	
27	0	24	15.974264	-0.01621397	-389.1353005	11610.9	389.1353	59	0.28		April	0	
28	0	25	16.022434	-0.04816983	-1156.075826	10843.9	1156.0758	58	0.25		May	0	
29	0	26	16.127075	-0.10464101	-2511.384229	9488.62	2511.3842	57	0.2		June	0	
30	0	27	16.018965	0.108109571	2594.629706	14594.6	0	56	0.25		July	0	
31	0	28	16.116425	-0.09745987	-2339.03698	12255.6	0	55	0.2		August	0	
32	0	29	16.026532	0.089893552	2157.445253	14413	0	54	0.24		September	0	
33	0	30	16.066293	-0.03976086	-954.2605843	13458.8	0	53	0.22		October	0	
34	0	31	15.999434	0.066858426	1604.602234	15063.4	0	52	0.25		November	0	
35	0	32	15.818839	0.180595021	4334.280509	19397.7	0	51	0.34		December	0	
36	0	33	15.805157	0.013682003	328.3680706	19726	0	50	0.35				
37	0	34	15.622892	0.182264847	4374.356321	24100.4	0	49	0.47		Account Deposits by Month	Options	
38	0	35	15.477679	0.145213616	3485.126781	27585.5	0	48	0.58		January	17280	
39	0	36	15.19678	0.280898418	6741.562028	34327.1	0	47	0.82		February	0	
40	0	37	15.175574	0.021206496	508.955909	34836	0	46	0.84		March	0	
41	0	38	15.134847	0.040726372	977.4329179	35813.5	0	45	0.88		April	0	
42	0	39	15.355417	-0.22056994	-5293.678482	30519.8	0	44	0.68		May	0	
43	0	40	15.471487	-0.11606964	-2785.671392	27734.1	0	43	0.58		June	0	
44	0	41	15.379381	0.092105737	2210.537685	29944.6	0	42	0.65		July	0	
45	0	42	15.35923	0.020150775	483.6185968	30428.3	0	41	0.67		August	0	
46	0	43	15.415105	-0.05587499	-1340.999879	29087.3	0	40	0.62		September	0	
47	0	44	15.281975	0.133130294	3195.127045	32282.4	0	39	0.74		October	0	
48	0	45	15.319492	-0.03751681	-900.4033411	31382	0	38	0.7		November	0	
49	0	46	15.308109	0.011382568	273.1816399	31655.2	0	37	0.71		December	0	
50	0	47	15.448321	-0.14021168	-3365.080271	28290.1	0	36	0.59				
51	0	48	15.281061	0.167259743	4014.23384	32304.3	0	35	0.73				
52	0	49	15.444571	-0.16350925	-3924.221982	28380.1	0	34	0.59				
53	0	50	15.396572	0.047998599	1151.966376	29532.1	0	33	0.63				
54	0	51	15.304334	0.092237564	2213.701527	31745.8	0	32	0.71				
55	0	52	15.292978	0.011356594	272.5582617	32018.3	0	31	0.72				
56	0	53	15.262726	0.030252238	726.0537199	32744.4	0	30	0.75				
57	0	54	15.321145	-0.05841973	-1402.073469	31342.3	0	29	0.69				
58	0	55	15.405944	-0.08479906	-2035.177543	29307.1	0	28	0.61				
59	0	56	15.371499	0.034445362	826.6886785	30133.8	0	27	0.64				
60	0	57	15.260814	0.11068461	2656.430646	32790.3	0	26	0.74				
61	0	58	15.249217	0.011597088	278.3301155	33068.6	0	25	0.75				
62	0	59	15.177626	0.071591093	1718.186223	34786.8	0	24	0.82				
63	0	60	15.31275	-0.13512382	-3242.971704	31543.8	0	23	0.69				
64	0	61	15.439562	-0.12681243	-3043.498394	28500.3	0	22	0.57				
65	0	62	15.440513	-0.00095093	-22.82231653	28477.5	0	21	0.57				
66	0	63	15.259448	0.181065252	4345.566044	32823	0	20	0.74				
67	0	64	15.391883	-0.13243469	-3178.432594	29644.6	0	19	0.61				
68	0	65	15.360114	0.031768464	762.4431406	30407.1	0	18	0.64				
69	0	66	15.573145	-0.21303044	-5112.73046	25294.3	0	17	0.45				
70	0	67	15.502248	0.070896707	1701.520962	26995.8	0	16	0.51				
71	0	68	15.456754	0.04549438	1091.865128	28087.7	0	15	0.55				
72	0	69	15.475709	-0.01895525	-454.9260149	27632.8	0	14	0.53				
73	0	70	15.512339	-0.03663044	-879.1305373	26753.7	0	13	0.49				
74	0	71	15.502136	0.010203019	244.8724659	26998.5	0	12	0.5				
75	0	72	15.565519	-0.06338272	-1521.185306	25477.3	0	11	0.44				
76	0	73	15.55711	0.008409368	201.8248241	25679.2	0	10	0.45				
77	0	74	15.530408	0.026701619	640.8388574	26320	0	9	0.47				
78	0	75	15.420915	0.109493441	2627.842593	28947.8	0	8	0.58				
79	0	76	15.557095	-0.13618061	-3268.334627	25679.5	0	7	0.44				
80	0	77	15.66827	-0.11117429	-2668.182869	23011.3	0	6	0.34				
81	0	78	15.39778	0.27048971	6491.753049	29503.1	0	5	0.6				
82	0	79	15.498784	-0.10100377	-2424.090595	27079	0	4	0.5				
83	0	80	15.396947	0.101836371	2444.072907	29523.1	0	3	0.6				
84	0	81	15.585003	-0.1880559	-4513.341557	25009.7	0	2	0.41				
85	0	82	15.504067	0.080935759	1942.458226	26952.2	0	1	0.5				

Modeling Futures Contract Hedging

The first alternative to cash marketing explored is hedging through the use of futures contracts. The evaluator worksheet for futures hedging and options is the link between the price generator and the values presented on the cash flow budget. The values presented in the cash flow budget from the evaluator include the costs to use the chosen risk management tool, the potential costs to maintain use of this tool, and the potential payoff associated with the use of this tool. These values are determined by the evaluator based upon the prices received from the price generator.

In the case of hedging using futures contracts, the evaluator calculates both deposits and margin calls occurring each month. Thus, information is gathered on milk sold each month as well as feeds purchased each month. Hence, information from one futures contract price series might be used as inputs for more than one month of feed purchases. The evaluator identifies this information based on both the futures contract month and the month which the feed transaction takes place.

An obvious difference in simulating selective hedging strategies, as opposed to calendar or time based strategies is the fact that positions will not be taken on the same trading day in all iterations. Thus, the model must be able to automatically adjust the information gathered from the price generator, such as beginning price levels and subsequent price changes, based upon the trading day on which the market trigger is reached. This automatic adjustment is accomplished by first setting a column in the evaluator which corresponds to the market signal table of the price generator. The evaluator links to the corresponding column in the market signal table and thus reflects whether a targeted margin was presented by the market on a particular trading day. The market signal column in the evaluator is set up to return only the first value where a targeted margin was met. It was assumed that the decision maker would take action on the first day the targeted margin was reached and that positions would be simultaneously taken in all corresponding contracts. The user can define, within the evaluator, which target margin to use for the simulation. Next, the evaluator uses lookup functions to create a column that shows the trading day in which the market trigger was reached and a set of contracts was purchased. Each of the subsequent prices until the close of the position is then returned to the next column in the evaluator. The subsequent prices are vital as they determine the net outcome, payoff less costs, of the risk management tool for that iteration. Once this information is obtained, the evaluator automatically calculates the initial account deposit, price changes and subsequent gains and losses to the account, cumulative account levels, and total margin calls.

As outputs to the cash flow budget, the evaluator for the futures contracts calculates the totals for initial deposits and margin calls across all contracts on a monthly basis. Calculating these costs is a critical feature as the cash flows necessary to maintain positions may not be evenly balanced across the contract months. As an example, depending upon the assumed starting prices of the price generator, contracts across all months of the year may be entered into during the beginning of the year, which may create large maintenance costs during the beginning of the year while the potential benefits would be spread evenly through the business year. Finally, the evaluator calculates the ending account balance for each contract, less brokerage fees, which becomes a source of cash in the month in which the position is closed. Values used for initial and maintenance margin requirements are based on information available from the CME Group website (www.cmegroup.com). An assumed value of $70 per round turn of each contract was made for the sake of simplicity. Actual fees may differ widely among brokers, however the model structure developed in this thesis allows for flexibility in this assumption. Assumptions related to hedging are listed in the table below.

Table 3. Hedging Assumptions

Commodity	Contract Size	Daily Limit Move	Initial Margin	Maintenance Margin	Broker Fee
Class III Milk	2,000 cwt.	$0.75	$1,000	$1,000	$70
Corn	5,000 bu.	$0.30	$1,500	$1,500	$70
Soybean Meal	2,000 tons	$20.00	$2,000	$2,000	$70

Modeling Hedging through Options on Futures Contracts

The second type of risk management tool considered is an option on a futures contract. Hedging with options involves purchasing the right but not the obligation to take a position in a futures contract at specified strike price. A producer can use options as a hedging mechanism by either exercising the option thus taking the associated position in the futures market or by closing out the option purchased by selling the option.

Options are available on commodity futures contracts at varying price levels ranging from those deep in the money to those well out of the money. An option is in the money if that option may be exercised immediately as its strike price is at a beneficial level relative to the market. In the money options command a high price or premium. Conversely, options whose strike price is at a disadvantaged level compared to the current market price are out of the money. In a simple case, if the strike price of an option is equal to the current market price this option is said to be at the money. For the purposes of this work, only the use of at the money options was simulated. This was done in order to allow comparison of the relative costs of futures contracts versus options as each strategy will be based upon the same beginning hedged price.

Option premiums are simulated within the same evaluator worksheet as futures contracts. For the sake of simplicity all options are treated as European type option, which can only be exercised upon their expiration date. When a market signal triggers the use of a futures contract, the evaluator simultaneously uses the entry price of the futures contract to calculate the beginning premium of an at the money option. Thus, the use of futures and options can be compared by the user based upon the same price series. In addition to the price series, the options section of the evaluator also calculates the duration, or the life of the option, based upon the difference between the final trading day associated with the milk sale or feed purchase and the day in which the option was bought. The volatility measure for each option premium is the same as that used in the price generator detailed earlier. The risk free rate is assumed to be five percent for the sake of simplicity. The option premiums are calculated using Black's option pricing formula for commodity contracts as shown below (Black; Hull).

$$\text{Call Premium} = e^{-rt}\left[F_0 N(d_1) - KN(d_{(2)})\right]$$

$$\text{Put Premium} = e^{-rt}\left[KN(-d_2) - F_0 N(-d_1)\right]$$

Where:
r = Risk-free rate
t = Time left to expiration (days)
F_0 = Futures price
K = Strike price

$$d_1 = \frac{\ln\left(\frac{F_0}{K}\right) + \sigma^2\left(\frac{T}{2}\right)}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{F_0}{K}\right) - \sigma^2\left(\frac{T}{2}\right)}{\sigma\sqrt{T}}$$

Option premiums typically do not change in value at the rate and magnitude as the underlying futures contract. The measure of this relationship is known as the delta value. The delta value in this thesis was assumed to be .5 thus option premium are assumed to change at half the rate of the futures contracts. Therefore a producer using options to gain the same hedging efficiency as futures contracts would need to buy twice as many options as futures contracts as is assumed in this thesis.

Simulation and Evaluation of Risk Management Tools

Cash marketing, hedging with futures contracts and options on futures contracts and other combinations of these tools are evaluated against price series generated through Monte Carlo simulation techniques. These various risk management tool combinations allow those willing to accept market risk associated with cash marketing and purchases in one area but not others to compare results of their chosen strategy against other tool combinations. The risk management tool combinations represent the variable portion of the marketing strategy whereas the fixed portions are the marketing triggers and the action to hedge once these triggers are met. The Pro-forma financial statements are used to develop marketing triggers and to evaluate the costs and benefits of each risk management approach. Key output variables include net farm income, total risk management costs, operating line borrowings and annual percent change in equity. The following table illustrates the various risk management tool combinations examined in this thesis. The names listed refer to both the marketing strategies and the risk management tool combinations discussed in this thesis. As defined earlier, results for marketing strategies include those iterations where no hedging occurred whereas results analyzed in reference to risk management tools are based on only those iterations where hedging was employed.

Table 4. Marketing Strategies and Risk Management Tool Combinations

		Milk Marketing Risk Management Tools		
		Cash	Futures	Options
Corn & Soybean Meal Purchasing Risk Management Tools	Cash	"Cash"	"Futures / Cash"	"Options / Cash"
	Futures	"Cash / Futures"	"Futures"	"Options / Futures"
	Options	"Cash / Options"	"Futures / Options"	"Options"

Simulations were performed using the @Risk add-in for Microsoft Excel. Each simulation included 5,000 iterations. Nine simulations are run in total with three marketing strategy environments for each of three debt levels. The following table illustrates the definition for each of the simulations.

Table 5. Simulation Definitions

Simulation	Farm	Equity	Volatility Parameters	% Milk Production Hedged
1	Low Debt	80%	Baseline	100%
2	Low Debt	80%	Doubled	100%
3	Low Debt	80%	Baseline	50%
4	Average Debt	64%	Baseline	100%
5	Average Debt	64%	Doubled	100%
6	Average Debt	64%	Baseline	50%
7	High Debt	30%	Baseline	100%
8	High Debt	30%	Doubled	100%
9	High Debt	30%	Baseline	50%

These marketing strategy environments represent the simulated market situation facing the decision maker and include a baseline scenario with parameters estimated based on historical data, an increased volatility environment, and finally a scenario in which only fifty percent of milk production is hedged for those strategies using risk management tools to price milk.

CHAPTER IV: DATA

This section serves as a brief summary of the data used in this work. Included in this chapter are the sources of the data used as well as a review of the characteristics of this data.

Data Used in Developing Pro-Forma Financial Statements

The data used in developing the pro-forma cash flow budget, income statement and balance sheets came from the Dairy Farm Business Summary (DFBS) conducted each year by Cornell University. As discussed in the methods section, values associated with dairy herds having more than 600 cows from summary years 2006 through 2008 was standardized on a per cow level. These calculated values were then used in developing the majority of the pro-forma financial statements. Exceptions to this process were discussed earlier in the methods section of this thesis. The standardized asset values from the DFBS are summarized in the following table.

Table 6. Asset Values per Cow - Herds with 600+ Cows

Asset Category	Jan. 1, 2007	Jan. 1, 2006	Jan. 1, 2005	Average Per Cow 2005-2007
Average Number Cows	1,019	1,021	1,078	1,039
Current Assets				
Farm cash, checking, savings	$46.24	$52.43	$38.65	$45.77
Accounts Receivable	$214.15	$241.07	$240.68	$231.97
Prepaid Expenses	$6.28	$10.54	$9.35	$8.72
Feed and Supplies	$701.02	$767.31	$677.31	$715.21
Intermediate Assets				
Livestock	$2,077.86	$2,044.11	$1,911.37	$2,011.12
Machinery and Equipment	$1,169.04	$1,142.19	$1,051.73	$1,120.99
Farm Credit Stock	$11.75	$22.74	$20.64	$18.38
Other Stock and Certificates	$170.89	$193.63	$201.03	$188.52
Long Term Assets				
Land and Buildings	$2,894.87	$2,554.60	$2,549.50	$2,666.33

In the following table, all liabilities from the large herd tables of the DFBS are listed as the standardized values used in this work. This was done in order to allow observation of all liability categories as these were used to establish proportions between liability categories in the amortization tables of the model.

Table 7. Liability Values Herds with 600+ Cows

Liability Category	Jan. 1, 2007	Jan. 1, 2006	Jan. 1, 2005	Average Per Cow 2005-2007
Average Number of Cows	1,019	1,021	1,078	1,039
Current Liabilities				
Accounts Payable	$147.81	$110.16	$147.82	$135.48
Operating Debt	$159.97	$148.51	$224.81	$178.63
Short Term	$19.50	$2.36	$11.70	$11.19
Current Portion-Intermediate	$212.96	$220.46	$224.69	$219.47
Current Portion-Long Term	$63.91	$53.45	$65.61	$61.07
Intermediate Liabilities	$1,354.28	$1,237.00	$1,246.99	$1,278.78
Long Term Liabilities	$1,070.28	$1,028.99	$1,066.04	$1,055.29
Total Farm Liabilities	$3,028.71	$2,800.92	$2,994.16	$2,942.18

In addition to asset and liability values, the DFBS was used to estimate revenue and expense category values. As described earlier, these values were calculated in a similar manner to values used in constructing the pro-forma balance sheets. The following table lists the standardized expense categories adapted from the DFBS. These expenses were treated as accrual expenses. The accounts payable were calculated in the manner described in the methods section.

Table 8. Accrual Expenses per Cow Herds with 600+ Cows

Expense Category	Jan. 1, 2005	Jan. 1, 2006	Jan. 1, 2007	Average Per Cow 2005-2007
Hired Labor	$718.16	$686.88	$713.39	$706.14
Professional Nutritional Services	$1.13	$0.48	$1.00	$0.87
Machine Hire, Rent and Lease	$48.84	$60.30	$83.28	$64.14
Machine Repairs and Farm Vehicle Expenses	$169.32	$167.82	$183.60	$173.58
Fuel, Oil and Grease	$117.50	$125.72	$147.88	$130.37
Breeding	$53.06	$54.95	$58.23	$55.42
Veterinary and Medicine	$157.22	$167.09	$160.99	$161.76
Milk Marketing	$174.56	$182.89	$185.34	$180.93
Bedding	$81.36	$80.01	$81.00	$80.79
Milking Supplies	$82.44	$83.41	$94.96	$86.94
Cattle Lease and Rent	$5.74	$4.63	$5.27	$5.21
Custom Boarding	$80.33	$79.95	$77.92	$79.40
bST expense	$62.33	$59.02	$74.21	$65.18
Livestock professional service	$10.08	$11.34	$11.76	$11.06
Other livestock expense	$21.82	$15.37	$17.43	$18.21
Fertilizer and Lime	$72.20	$64.47	$84.11	$73.59
Seeds and plants	$49.54	$50.51	$65.92	$55.32
Spray and other crop expense	$36.86	$40.66	$50.45	$42.66
Crop professional fees	$6.11	$4.78	$6.23	$5.71
Land, building and fence repair	$59.35	$54.81	$79.24	$64.47
Taxes and rent	$113.34	$106.82	$119.76	$113.31
Utilities	$85.77	$88.00	$97.51	$90.43
Misc. (including insurance)	$57.21	$62.46	$69.30	$62.99
Machinery Depreciation	$187.84	$172.50	$191.08	$183.81
Building Depreciation	$123.74	$124.52	$120.55	$122.94
Interest paid	$152.28	$184.71	$198.37	$178.46

As can be seen from the table, feed costs were not calculated in the same manner as other categories. Corn and soybean meal prices, and thus their associated total annual expenses, were treated as random variables while other ration ingredients were priced at fixed levels. Despite being non-cash in nature, depreciation expenses were included in this table for the sake of simplicity. In addition, accrual interest expenses are included in order to allow for observation of the figures used as a guide in developing the amortization tables.

In order to translate both the simulated and assumed feed prices into line item expenses a ration formulated for eighty pounds of milk per cow per day was used. This ration is as follows and is based upon Garcia, et al.

Table 9. Assumed Ration for Dairy Cow Producing Eighty Pounds of Milk Daily

Ration Ingredient	Pounds As Fed	Unit Price ($)	Unit
Alfalfa Hay	5.43	142	Ton
Haylage	19.58	45	Ton
Corn Silage	40	25	Ton
Corn Grain	18.18	Random	Bushel
Dried Distiller's Grain	5.43	165	Ton
Soybean Meal	2.25	Random	Ton
Vitamins and Minerals	0.87	12.8	cwt

Although milk sales provide the large majority of revenue, other categories were modeled as well in order to provide more accurate reflection of an actual dairy farm. These categories are shown below.

Table 10. Revenues per Cow Herds with 600+ Cows

Revenue Category	Jan. 1, 2005	Jan. 1, 2006	Jan. 1, 2007	Average Per Cow 2005-2007
Dairy Cattle (Cull Cows)	$251.61	$268.63	$282.52	$267.59
Dairy Calves	$73.18	$69.06	$28.94	$57.06
Miscellaneous Receipts	$153.82	$165.67	$125.13	$148.21

This completes the review of data used in constructing the pro-forma financial statements. All other categories in the financial statements were estimated based upon state-wide summary figures from the DFBS. These figures, such as “Gross Family Living Withdrawals” were estimated like the other expense categories.

Data Used in Developing Simulation Model Parameters

Market prices for milk, corn, and soybean meal were simulated using the lognormal model typically used in modeling random walks of stock prices. Daily prices on Class III milk, corn, and soybean meal futures contracts were used to estimate the required parameters. Data was gathered from the Dairy Marketing and Risk Management Program website sponsored by the University of the Wisconsin (http://future.aae.wisc.edu). Descriptive statistics of this data are available in the table on the following page. Daily price changes from the entire life of each contract were used to estimate the distribution and annualized volatility. Price information was gathered from contracts expiring in calendar years 2003 through 2008. All prices for each commodity contract were analyzed using the distribution fitting capabilities of the @Risk add-in for Excel. Distributions were determined to be best fit based upon the resulting Chi-square values. These distributions were then used to generate random beginning prices for each commodity contract price series. The calculated parameters are summarized, by price year, in the following tables beginning with a summary of the historical data and followed by a table regarding the parameters estimated from the historical futures contract data.

Table 11. Historical Data Summary – Milk, Corn, Soybean Meal Futures Contracts

Commodity	Contract Month	Begin Date	End Date	Mean	Standard Deviation	Minimum	Maximum	Median	Skewness	Kurtosis	Observations
Class III Milk	1	2/8/2000	2/1/2008	12.42	1.63	9.45	20.12	12.02	1.78	7.29	2,795
	2	2/1/2000	2/29/2008	12.32	1.55	9.55	19.12	12	1.36	5.29	2,879
	3	2/1/2000	4/4/2008	12.39	1.7	9	18.6	12	1.19	4.58	2,811
	4	2/1/2000	5/1/2008	12.45	1.76	9.3	19.65	12	1.22	4.74	3,071
	5	2/1/2000	5/30/2008	12.66	2	9.38	20.6	12.15	1.36	5.19	3,041
	6	2/1/2000	7/2/2008	12.98	2.11	9.45	20.95	12.4	1.35	4.92	3,018
	7	2/1/2000	7/31/2008	13.39	2.11	9.25	22.3	12.85	1.5	5.89	3,122
	8	2/1/2000	9/5/2008	13.65	2.08	9.25	21.4	13.15	1.26	4.86	3,180
	9	2/1/2000	10/3/2008	13.94	2.08	9.81	21.25	13.42	1.25	4.81	3,220
	10	2/1/2000	10/31/2008	13.65	2.01	9.86	21.13	12.97	1.36	4.89	3,305
	11	2/1/2000	12/5/2008	13.3	2.05	8.5	20.93	12.75	1.33	5.02	3,371
	12	2/1/2000	13/31/2008	13.11	2.14	8.93	20.92	12.43	1.43	5.09	3,467
Corn	3	9/20/2001	2/1/2008	2.75	0.6	1.95	5.12	2.52	1.48	4.59	2,808
	5	1/2/2002	2/1/2008	2.81	0.63	1.95	5.24	2.54	1.25	3.79	2,549
	7	6/7/2001	7/14/2008	2.91	0.82	2.04	7.55	2.59	2.51	10.47	3,510
	9	3/20/2002	9/12/2008	3.02	0.98	1.95	7.68	2.58	2.01	7.34	2,685
	12	3/6/2001	12/12/2008	2.87	0.85	1.86	7.88	2.54	2.54	10.82	4,506
Soybean Meal	3	12/18/2001	12/7/2007	191.69	33.41	144	318.2	183.4	1.06	3.78	1,937
	5	1/2/2002	12/7/2007	194.86	37.24	145	336	185.4	1.33	4.67	1,984
	7	1/8/2002	7/14/2008	208.29	54.42	147	453.9	190.6	1.72	5.89	2,359
	8	3/18/2002	8/14/2008	210.26	54.66	147.2	445.9	191.8	1.71	5.82	2,293
	9	3/22/2002	9/12/2008	207.64	52.72	147	441.1	190.1	1.78	6.21	2,413
	10	1/28/2002	10/14/2008	201.45	49.5	147.1	432.2	186.15	1.85	6.7	2,606
	12	1/29/2002	12/12/2008	202.22	49.3	147	429	186.75	1.65	5.9	2,878

Table 12. Estimated Parameters and Statistics for Generated Beginning Market Prices

Commodity	Month	Annualized Volatility	Mean	Standard Deviation	Minimum	Maximum	Median	Skewness	Kurtosis
Class III Milk	1	0.1	12.35	1.47	8.23	+Infinity	12.13	2.12	19.94
Class III Milk	2	0.1	12.28	1.48	8.05	+Infinity	12.06	2.07	19.05
Class III Milk	3	0.12	12.35	1.71	7.77	+Infinity	12.08	2.27	23.47
Class III Milk	4	0.1	12.45	1.71	7.23	+Infinity	12.19	0.98	4.61
Class III Milk	5	0.1	12.66	2.17	8.34	+Infinity	12.26	3.89	265.99
Class III Milk	6	0.12	12.98	2.34	8.62	+Infinity	12.53	4.59	+Infinity
Class III Milk	7	0.13	13.35	2.15	8.43	+Infinity	12.97	2.96	51.65
Class III Milk	8	0.13	13.6	2.12	8.17	+Infinity	13.26	2.43	27.89
Class III Milk	9	0.13	13.91	2.15	8.55	+Infinity	13.56	2.53	31.11
Class III Milk	10	0.12	13.6	2.08	9.1	+Infinity	13.23	3.29	79.61
Class III Milk	11	0.12	13.18	1.93	7.42	+Infinity	12.9	1.93	16.58
Class III Milk	12	0.12	13.01	2.09	8.15	+Infinity	12.65	2.87	46.01
Corn	3	0.19	2.75	0.8	1.88	+Infinity	2.58	+Infinity	+Infinity
Corn	5	0.2	2.82	0.75	1.7	+Infinity	2.63	4.72	177.73
Corn	7	0.19	2.91	0.93	1.9	+Infinity	2.67	25.08	+Infinity
Corn	9	0.2	3.02	0.96	1.91	+Infinity	2.72	2.59	14.22
Corn	12	0.18	2.81	0.87	1.83	+Infinity	2.63	+Infinity	+Infinity
Soybean Meal	3	0.23	191.71	33.06	144	553.74	184.67	1.13	4.48
Soybean Meal	5	0.23	195.34	42.04	118.31	+Infinity	185.07	3.11	32.61
Soybean Meal	7	0.24	208.29	55.35	135.18	+Infinity	192.38	2.27	11.6
Soybean Meal	8	0.25	210.26	55.48	136.43	+Infinity	194.38	2.25	11.47
Soybean Meal	9	0.24	207.64	53.32	137.01	+Infinity	192.33	2.26	11.55
Soybean Meal	10	0.35	201.45	51.27	138.1	+Infinity	186.2	2.43	12.82
Soybean Meal	12	0.23	202.22	53.69	139.04	+Infinity	185.88	2.55	13.83

As shown in the table above, data was only used beginning with the year 2000 as this corresponds approximately to the implementation of current Federal Milk Marketing Order policies. Thus, although additional data does exist for the Class III Milk contract, the data used within this thesis was chosen in order to better reflect the current market structure. In contrast to the current milk pricing structure though, this model departs from the price support program and thus makes no requirement that simulated prices fall above a certain level. This approach was used in order to again represent a fully random market potentially faced by producers.

CHAPTER V: RESULTS

This chapter reviews and analyzes the results of the simulation described earlier. Three simulations were completed for each debt level thus nine simulations are reviewed and analyzed in total. Theory related to hedging predicts that hedging will reduce the variance of net farm income but at the same time reduce the expected return over time. This pattern was seen in the results presented here. The expected return on average should be slightly lower for the hedger as an expected positive return is needed to induce the speculator to take the opposite position in the market (Hull). This thesis was structured to estimate the costs and returns associated with various risk management tools as these are typically not illuminated. Based on these premises the results are reviewed in the following manner. First, the prices generated within the simulation are reviewed in order to gain insight on the market environment in which the risk management strategies were employed. Second the performance of the risk management strategies is presented as measured by net farm income. These results enable observation of risk management strategy performance in terms of changes in the absolute level of net farm income and effects on net farm income variance. Measures of risk management costs are then presented, which allows the decision maker to evaluate the investment required for each marketing strategy and risk management tool combination. These expected costs can then be used to further weight the relative effectiveness of each marketing strategy in reducing variance of net farm income. In this manner a simple return measure using the change in standard deviation as compared to the cash marketing strategy is presented as an additional way to judge the relative effectiveness of each marketing strategy. Analysis of the effects and costs of risk management is taken one step further by analyzing the simulation data in order to categorize the results based on those instances where the net farm income of a given risk management strategy was above or below that of the cash marketing strategy, thus allowing a decision maker to evaluate marketing strategies in a manner designed to elicit possible regret over forfeited income. Finally, borrowed funds required to use various risk management strategies are presented along with the associated effects on the ending balance sheet of the operation. These measures allow for complete analysis of the performance of various risk management strategies and tools in both absolute and relative terms. This information gives a decision maker the ability to compare the attractiveness of risk management activities with that of other capital investment opportunities. In addition, this information provides background information for lenders working with commodity producers wishing to implement a marketing plan.

The results are organized by debt level beginning with the simulated low debt farm and ending with the high debt farm. Within each debt level, the baseline simulation is presented first as a means for comparison to the remaining simulations. The results for each simulation are made up of 5,000 iterations.

Following summarization of the results it was determined that the ending premiums on the modeled options had been incorrectly calculated. As described earlier, the delta factor associated with the behavior of option premiums was included in the model by requiring an increased number of options proportional to the assumed delta value to be purchased. However the effect of the assumed smaller rate of change in options premiums, approximated by the delta value, was not incorporated into the ending premium values. Thus, while the costs associated with the use of options are correctly estimated, the resulting payoffs are likely slightly overestimated. Caution should then be used in interpreting the results as the effect on net farm income variance reduction will also be slightly inflated.

Low Debt Farm – Baseline Simulation

The baseline simulation incorporates the parameters estimated from historical milk, corn, and soybean meal prices as discussed in the previous chapter. As shown below, the average prices generated by the simulation model are relatively on par with the average historical prices presented in Table 11. In the following table, descriptive statistics on the price levels at which hedging occurred are presented. Milk prices show the largest difference, as a percentage, in the opening hedge price versus the ending futures market price.

The market prices shown below illustrate why simulation results must be examined in a thoughtful manner. While the average prices correspond well with historical prices, the extreme values appear to be somewhat unrealistic. This is especially true with regard to the corn prices generated as the maximum prices are upwards of ten times the average price. Examination of results should be kept in context of the generated prices and input assumptions. While these values could be considered unfathomable and discarded, this work includes all generated prices in order to demonstrate the effects of a completely random market on the financial health of a dairy operation.

The prices in the table below are the closing price at the time of expiration for each contract. These prices as well as the opening hedge prices presented in the table afterwards do not include the assumed basis values.

Table 13. Simulation 1 - Low Debt Farm –Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.35	$8.92	$30.19	$2.75	$1.89	$24.21	$191.72	$140.90	$382.45
February	$12.28	$8.56	$28.95	$2.75	$1.70	$24.14	$191.76	$121.78	$386.04
March	$12.35	$8.20	$30.78	$2.75	$1.65	$26.35	$191.81	$105.68	$391.39
April	$12.45	$8.31	$22.66	$2.82	$1.57	$13.21	$195.37	$104.81	$884.00
May	$12.67	$7.93	$45.48	$2.82	$1.38	$13.70	$195.38	$100.18	$906.74
June	$12.97	$7.85	$48.65	$2.90	$1.39	$18.12	$208.15	$94.87	$882.14
July	$13.35	$7.84	$46.25	$2.90	$1.42	$19.32	$208.14	$92.40	$888.32
August	$13.61	$7.41	$34.66	$3.01	$1.36	$11.53	$210.01	$81.97	$965.77
September	$13.91	$7.17	$43.85	$3.01	$1.28	$11.65	$207.91	$85.12	$841.16
October	$13.60	$7.45	$38.02	$2.81	$1.24	$33.59	$201.42	$52.88	$925.61
November	$13.18	$7.30	$37.83	$2.81	$1.26	$33.52	$202.08	$79.15	$1,167.72
December	$13.01	$7.25	$48.63	$2.81	$1.21	$32.93	$202.01	$75.44	$1,254.90

Table 14. Simulation 1 – Low Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	179	$17.02	$29.29	$15.65
	2	327	$16.06	$28.36	$14.62
	3	543	$15.99	$31.57	$14.65
	4	927	$15.29	$24.52	$13.44
	5	1,058	$15.82	$48.51	$13.64
	6	1,091	$16.39	$42.71	$14.50
	7	1,509	$13.65	$29.70	$8.25
	8	1,824	$13.94	$31.02	$8.88
	9	2,185	$13.57	$34.04	$9.06
	10	1,856	$15.90	$37.46	$14.39
	11	1,583	$15.73	$33.65	$14.43
	12	1,486	$15.85	$46.76	$14.46
Corn	2	289	$2.64	$5.64	$1.89
	3	475	$2.66	$9.74	$1.96
	4	923	$2.73	$7.62	$1.94
	5	1,052	$2.70	$6.30	$1.54
	6	1,031	$2.80	$13.39	$1.84
	7	1,438	$2.77	$9.41	$1.57
	8	1,748	$2.83	$8.79	$1.64
	9	2,114	$2.84	$10.21	$1.45
	10	1,791	$2.69	$8.37	$1.42
	11	1,537	$2.68	$7.68	$1.53
	12	1,425	$2.70	$6.45	$1.46
Soybean Meal	2	289	$190.79	$299.20	$135.27
	3	475	$189.29	$333.87	$134.06
	4	923	$198.74	$854.54	$119.20
	5	1,052	$197.09	$657.16	$121.02
	6	1,031	$204.96	$615.11	$115.47
	7	1,438	$207.42	$604.77	$97.61
	8	1,748	$206.12	$789.39	$102.07
	9	2,114	$205.66	$782.92	$99.27
	10	1,791	$199.44	$588.18	$86.34
	11	1,537	$200.86	$570.26	$93.70
	12	1,425	$198.75	$611.84	$94.93

In the above table, the number of iterations in which hedging occurred, for each commodity contract, is presented along with the average, minimum and maximum opening hedge price. Across all commodity contracts, hedging occurred on average in 1,242 iterations. Because the model is structured as beginning all simulated prices in January, the number of iterations in which hedging occurred increased in the later contract months as these contracts were simulated over a longer lifespan thus creating more opportunities along the price path in which the desired margin might be presented. The average opening hedge prices across all contracts for milk, corn and soybean meal were \$15.43, \$2.73, and \$199.92 respectively. These prices are well within reason compared to the historical prices summarized earlier with the opening hedge price on the milk contract slightly above the historical average of \$13.02. Of particular note when examining this table for this and all other simulation is the range of prices at which marketing strategies were triggered. In this simulation for the low debt farm, marketing strategies were triggered in iterations with a milk price as low as \$8.25 and in other iterations with corn and soybean meal prices as high as \$13.39 and \$789.39 respectively. This illustrates the importance of using margins as a decision criterion for marketing strategies as reliance solely on historic price ranges could lead to missed profit opportunities.

For the baseline simulation, the risk management strategy with the highest average net farm income was the marketing strategy employing the use of options on both milk sales and feed purchases. Within the review of each simulation, the cash marketing strategy is treated as the benchmark as all other marketing strategies are compared relative to this approach. Based on this, the average net farm income of the options strategy is just over \$700 above the cash marketing strategy. In total, three marketing strategies resulted in average net farm income levels above the cash marketing strategy all of which included the use of options. These outcomes are based upon the nature of the options, which as a risk management tool protects against lower milk prices and higher feed prices while at the same allowing for potential beneficial prices such as milk prices above and feed prices below the hedged prices associated with the option. This slight upside potential associated with the use of options is shown in the graph below and in Table 15.

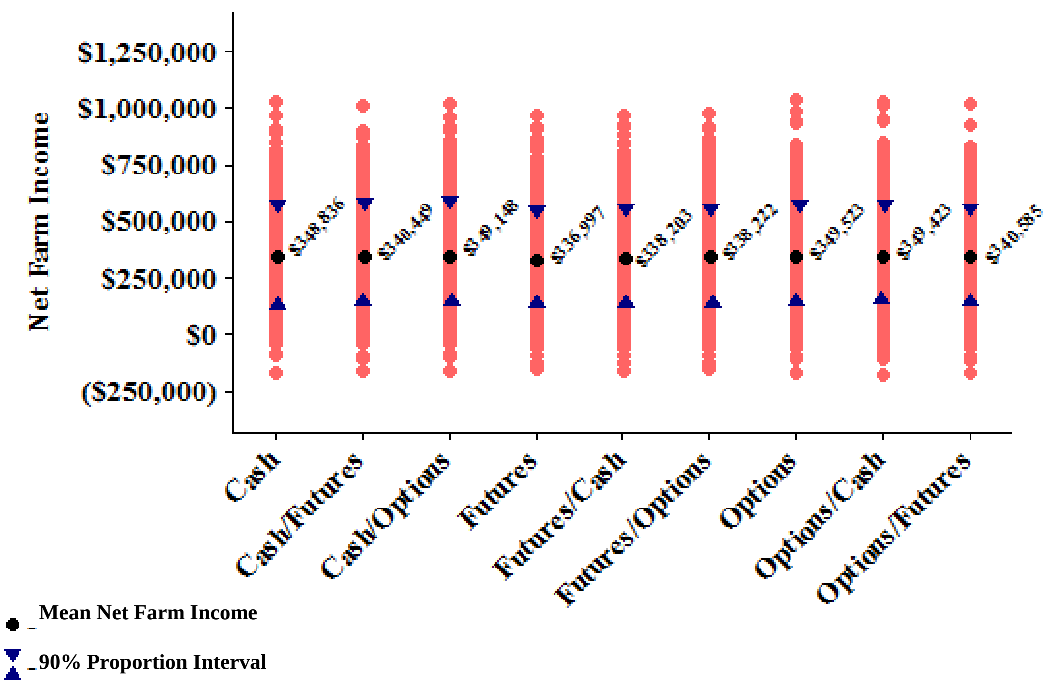

Figure 5. Simulation 1 – Low Debt Farm – Net Farm Income

Across all marketing strategies, those using risk management tools reduced the standard deviation of net farm income as compared to the cash marketing strategy. This result is predicted by hedging theory as hedging is viewed as a means to reduce the variation in market prices. The use of futures contracts to hedge milk prices resulted in the largest decrease in net farm income variance. The only marketing strategy that did not reduce the variance in net farm income was the use of options on feed purchases, however this increased variance is due to the higher upside associated with this strategy. An additional manner of differentiating the success of each marketing strategy is to analyze the range in which the simulated net farm income values fall. The 90% proportion interval is used as a baseline measure in this work. This measure illustrates the range of values which an operator could be 90% sure that the net farm income associated with each marketing strategy would fall based upon the market conditions simulated. These ranges are shown in the table below as well as the preceding figure.

Table 15. Simulation 1 – Low Debt Farm – Net Farm Income Summary

Marketing Strategy	Average	Standard Deviation	C.V.	Minimum	Maximum	5%	95%
Cash	$348,836	$131,674	37.75%	($173,486)	$1,027,746	$150,362	$577,534
Cash / Futures	$340,449	$128,532	37.75%	($164,661)	$1,005,962	$146,060	$562,139
Cash / Options	$349,148	$131,985	37.80%	($162,465)	$1,021,305	$148,721	$577,926
Futures	$336,997	$124,304	36.89%	($156,077)	$971,208	$147,169	$552,455
Futures / Cash	$338,203	$124,726	36.88%	($164,530)	$965,891	$147,657	$553,868
Futures / Options	$338,222	$124,881	36.92%	($153,557)	$974,110	$146,961	$554,714
Options	$349,523	$131,010	37.48%	($173,184)	$1,036,926	$151,542	$579,229
Options / Cash	$349,423	$130,829	37.44%	($184,155)	$1,028,717	$151,815	$574,927
Options / Futures	$340,585	$127,360	37.39%	($175,378)	$1,021,823	$147,291	$561,999

While a decision maker is unable to know whether future market conditions will correspond to any simulated market environments, analyzing the intervals and ranges within which net farm income can be expected to fall allows the decision maker to visually and quantitatively analyze the shifts in net farm income associated with each marketing strategy. These shifts are in terms of both absolute net farm income and in precision. For instance, the options strategy shown in the table above shifts the 90% proportion range upward in absolute terms however the precision of that range is slightly lower than the cash marketing strategy as it encompasses a wider range of values.

Combining the analysis of these shifts with information regarding the potential costs associated with each of the risk management tools allows the decision maker to perform an elementary willingness to pay exercise. Providing additional information on the returns associated with the capital invested in risk management tools allows for a more complete analysis of marketing strategies by the decision maker. In this work, returns are based on the difference between the standard deviation of net farm income of a given risk management strategy and the baseline approach of the cash marketing strategy. Thus this simple return measure yields information on the investment required to attain a given level of variance reduction.

Table 16. Simulation 1 - Low Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Marketing Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,364	$25,794	67.2%	$195,480
Cash / Options	$12,760	$6,900	54.1%	$38,642
Futures	$128,757	$78,136	60.7%	$519,747
Futures / Cash	$102,223	$66,159	64.7%	$442,793
Futures / Options	$114,983	$71,682	62.3%	$479,175
Options	$71,104	$38,209	53.7%	$246,142
Options / Cash	$58,344	$31,637	54.2%	$209,760
Options / Futures	$96,708	$54,191	56.0%	$383,211

As shown in the table above, the use of futures contracts had the highest total costs on average. For futures contracts, both account deposits and margin calls are included in calculating total costs while costs for options are considered to be the premiums paid. In addition to having the highest total costs, the costs associated with those marketing strategies employing the use of futures contracts also tended to be more variable. This seems logical as one of the main selling points in the use of options to manage risk is the ability to know when and how much investment is required in order to hedge.

Table 17. Simulation 1 – Low Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($8,387)	($3,142)	($30,608)	($11,094)	8.19%
Cash / Options	$313	$311	($17,461)	$2,033	-2.43%
Futures	($11,839)	($7,370)	($73,947)	($21,887)	5.72%
Futures / Cash	($10,633)	($6,948)	($70,811)	($20,961)	6.80%
Futures / Options	($10,613)	($6,793)	($73,565)	($19,419)	5.91%
Options	$687	($664)	$8,879	$515	0.93%
Options / Cash	$587	($845)	$11,641	($4,061)	1.45%
Options / Futures	($8,251)	($4,314)	($4,031)	($12,464)	4.46%

As shown in the preceding table, the strategy employing only futures contracts on feed pricing resulted in the highest average return. However this marketing strategy only generated the fourth largest standard deviation reduction in absolute terms.

The following table provides descriptive statistics on the total costs associated with each risk management tool combination. These total costs include premiums for the options and both account deposits and total margin calls for futures contracts. The combination of "Cash / Options" had the lowest total costs on average while the use of futures contracts on both milk and feed resulted in the highest average costs. In general, those strategies employing the use of options had lower average and maximum costs than comparable strategies using futures contracts.

The results presented in the table below are based on those iterations within the simulation in which hedging occurred thus isolating the costs and returns of the risk management tool in question. Hedging occurred in 4,832 iterations of the 5,000 total iterations thus expenses are averaged over only those iterations where hedging took place.

Table 18. Simulation 1 – Low Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,798	4,798	4,832	4,832	4,832	4,832	4,832	4,832
Mean	$39,979	$13,298	$133,234	$105,777	$118,981	$73,576	$60,372	$100,070
Standard Deviation	$25,075	$6,517	$75,638	$64,446	$69,580	$36,452	$30,219	$51,983
Median	$35,074	$12,573	$121,480	$94,126	$107,634	$69,561	$57,120	$93,277
5%	$7,424	$3,945	$29,860	$20,996	$25,643	$21,673	$17,280	$26,502
95%	$87,541	$25,064	$276,096	$227,717	$249,834	$138,874	$114,720	$193,988
Minimum	$5,000	$494	$12,000	$12,000	$12,000	$960	$960	$960
Maximum	$195,480	$38,642	$519,747	$442,793	$479,175	$246,142	$209,760	$383,211
Skew	1.02	0.54	0.86	0.99	0.93	0.53	0.56	0.63
Kurtosis	1.34	-0.02	0.78	1.18	0.99	-0.01	0.05	0.23

The costs and returns of the various marketing tools are analyzed further by categorizing the results based upon whether or not the ending net farm income was below or above the cash marketing baseline. Looking at the results in this manner, the use of futures contracts appears less favorable as the average difference below cash was much lower than the difference below cash associated with the use of options on pricing milk. The average difference above the cash marketing strategy was greatest for those marketing tool combinations employing the use of options in pricing milk.

Table 19. Simulation 1 – Low Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	Average Difference Below	Average Total Risk Management Costs	Average Difference Above	Average Total Risk Management Costs
Cash / Futures	($12,581)	$46,307	$3,852	$20,793
Cash / Options	($4,566)	$12,915	$6,859	$13,811
Futures	($34,695)	$154,622	$23,760	$99,533
Futures / Cash	($33,653)	$126,301	$23,811	$74,756
Futures / Options	($33,806)	$139,466	$24,584	$87,560
Options	($24,807)	$72,469	$35,549	$75,101
Options/ Cash	($24,349)	$59,823	$35,768	$61,153
Options / Futures	($30,629)	$102,271	$33,492	$95,887

In addition to the effects of various marketing strategies on the net farm income of the dairy operation, this work allows for observation of the effects on the balance sheet. The capital necessary to implement a marketing plan and its use of various risk management tools must be sourced from surplus cash funds or must be financed. As investments in risk management tools for this model represent an additional use of cash funds, it is expected that on average the total funds borrowed against the operating line for any given risk management strategy will be greater relative to the cash marketing strategy. This is shown in the following tables. As expected, the cash marketing strategy results in the highest percent change in equity due to the lowest amount of additional operating funds borrowed.

Table 20. Simulation 1 – Low Debt Farm – Operating Line Borrowed

Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$74,194	$14,789	$982,542
Cash / Futures	$113,263	$19,137	$993,018
Cash / Options	$89,908	$15,988	$988,215
Futures	$382,221	$51,851	$1,055,125
Futures / Cash	$274,049	$38,578	$1,027,777
Futures / Options	$329,818	$44,497	$1,040,555
Options	$234,266	$29,535	$1,026,305
Options / Cash	$188,038	$25,608	$1,013,527
Options / Futures	$292,288	$39,000	$1,047,601

Table 21. Simulation 1 – Low Debt Farm – Percent Change in Equity

Marketing Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	8.4%	-0.7%	20.3%
Cash / Futures	7.8%	-1.1%	19.3%
Cash / Options	8.2%	-1.0%	20.0%
Futures	6.3%	-2.4%	15.9%
Futures / Cash	6.7%	-2.0%	16.5%
Futures / Options	6.5%	-2.3%	16.2%
Options	7.2%	-1.8%	18.6%
Options / Cash	7.4%	-1.5%	18.9%
Options / Futures	6.8%	-1.9%	18.0%

In summary, the choice between various risk management strategies is not an easy task and is directly dependent upon how the decision maker frames the goal of their risk management plan. As discussed earlier, success of a risk management can be interpreted differently depending on how the measure of success is defined. As shown in the preceding tables, one could argue that several risk management strategies represent the best choice. For example, while combinations using future contracts to price milk appear to have an advantage in reducing the variance in net farm income levels, options based strategies offer higher levels of net farm income on average. At the same time the costs associated with the use of futures including both account deposits and margin calls are much higher but are coupled with higher returns due to greater reductions in net farm income variance. This demonstrates the difficulty in making any type of across the board recommendation regarding the use of a particular risk management strategy. These tables do however allow a decision maker to observe the performance of each risk management strategy and tool and to formulate their own preference and weighting for each measure in order to determine the risk management tool combinations best suited to their own operation and business goals.

Low Debt Farm – Doubled Volatility Simulation

This simulation adjusts only the volatility parameter in this price generating formula discussed in the preceding chapter, all other parameters and assumptions match the baseline simulation. This allows for the effects of increasing volatility on the relative success of various risk management strategies to be isolated and observed. For this simulation, as well as the comparable simulations for the other debt levels, the volatility parameter for each commodity contract was doubled.

The average prices generated by this simulation are in line with both the historical data as well as the baseline simulation. The increased volatility did result in a broader range of prices however. This should then translate into a wider range of net farm income results. Although volatility is a term often associated with negative consequences in markets, by definition volatility refers only to the magnitudes and frequency of changes and thus allows for both much higher as well as much lower values for net farm income.

Table 22. Simulation 2 – Low Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.36	$8.50	$49.12	$2.75	$1.83	$20.43	$191.73	$137.32	$363.16
February	$12.28	$7.72	$53.29	$2.75	$1.53	$24.30	$191.72	$97.87	$452.14
March	$12.34	$6.32	$35.98	$2.75	$1.23	$20.62	$191.72	$88.91	$452.00
April	$12.46	$6.94	$26.90	$2.82	$1.21	$11.43	$195.24	$63.18	$863.67
May	$12.66	$6.77	$45.98	$2.82	$0.88	$10.79	$195.30	$62.47	$932.73
June	$12.99	$5.85	$65.33	$2.91	$0.91	$24.78	$208.32	$59.82	$1,225.07
July	$13.35	$5.34	$46.33	$2.91	$0.91	$27.53	$208.43	$46.32	$1,234.27
August	$13.61	$5.40	$55.67	$3.01	$0.75	$24.38	$209.99	$47.80	$1,311.12
September	$13.90	$4.83	$55.38	$3.01	$0.71	$26.68	$207.41	$38.07	$1,222.94
October	$13.59	$5.92	$37.63	$2.81	$0.87	$17.80	$200.67	$15.23	$2,483.09
November	$13.19	$4.48	$41.21	$2.81	$0.76	$18.23	$202.73	$30.02	$1,353.65
December	$13.01	$4.90	$37.74	$2.81	$0.71	$21.43	$202.94	$27.61	$1,471.01

Table 23. Simulation 2 – Low Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	237	$16.82	$47.21	$15.65
	2	509	$15.76	$53.68	$14.58
	3	951	$15.62	$31.21	$14.51
	4	1,378	$15.03	$23.84	$13.71
	5	1,607	$15.37	$39.59	$13.67
	6	1,795	$15.92	$55.28	$14.43
	7	2,283	$13.60	$49.06	$7.22
	8	2,715	$13.92	$57.74	$6.20
	9	3,053	$13.63	$39.13	$7.90
	10	2,795	$15.66	$39.13	$14.24
	11	2,513	$15.52	$31.33	$14.19
	12	2,428	$15.58	$39.71	$14.16
Corn	2	389	$2.62	$7.38	$1.66
	3	748	$2.64	$5.76	$1.46
	4	1,338	$2.68	$7.14	$1.36
	5	1,557	$2.71	$8.67	$1.45
	6	1,650	$2.75	$13.08	$1.41
	7	2,201	$2.78	$9.42	$1.16
	8	2,616	$2.84	$9.79	$1.06
	9	2,980	$2.88	$11.98	$1.12
	10	2,724	$2.70	$10.02	$0.98
	11	2,427	$2.69	$12.09	$1.12
	12	2,361	$2.71	$15.08	$0.96
Soybean Meal	2	389	$188.57	$335.85	$127.70
	3	748	$189.45	$394.97	$107.59
	4	1,338	$196.54	$664.63	$78.01
	5	1,557	$196.27	$546.25	$87.98
	6	1,650	$204.26	$1,179.02	$72.35
	7	2,201	$205.14	$721.90	$79.25
	8	2,616	$208.16	$693.96	$53.85
	9	2,980	$207.64	$732.47	$65.55
	10	2,724	$198.47	$762.16	$35.49
	11	2,427	$198.86	$796.48	$51.81
	12	2,361	$199.69	$874.34	$57.78

The figure below illustrates the net farm income levels resulting from the use of the risk management strategies considered in this work. Again, the strategies employing the use of options provided higher levels of net farm income on average as well higher potential maximum net farm income levels.

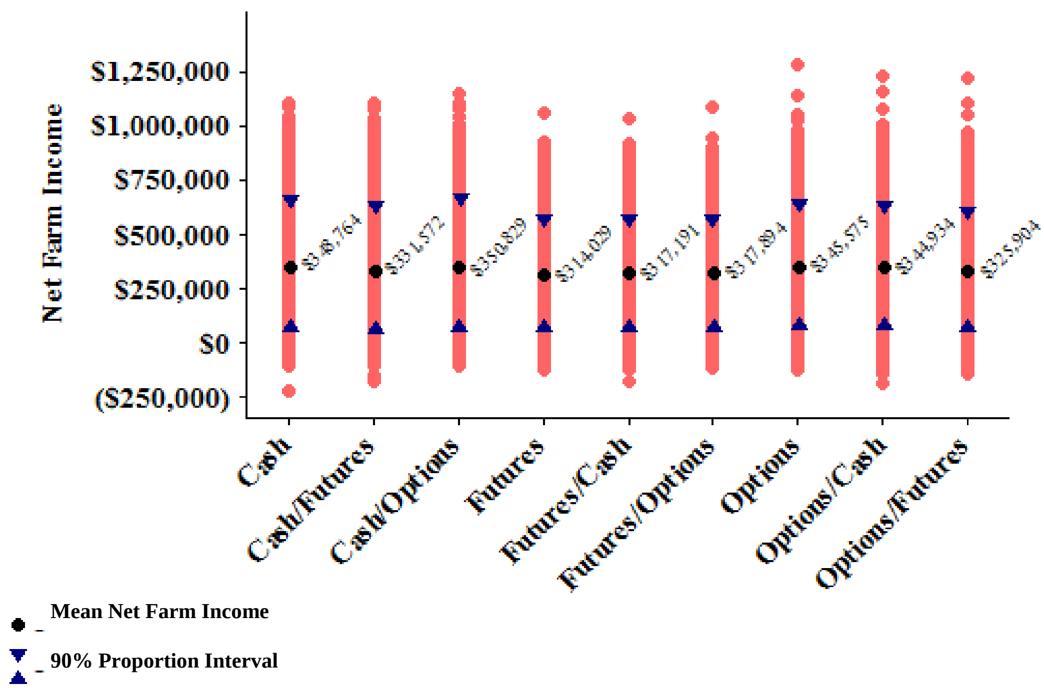

Figure 6. Simulation 2 – Low Debt Farm – Net Farm Income

In addition, the use of futures contracts again provided the greatest reduction in the variance of net farm income similar to the results of the baseline simulation. This variance reduction effect increased as the volatility parameter increased from the baseline simulation. The variance reduction effect, as measured by the differences in the coefficient of variation among the strategies, was nearly two to three times greater than the variance reduction provided by the use of futures contracts in the baseline simulation. While those marketing strategies employing the use of futures contracts again generally provided the largest reduction in net farm income this simulation

Table 24. Simulation 2 – Low Debt Farm – Net Farm Income Summary

Marketing Strategy	Average	Standard Deviation	C.V.	Minimum	Maximum	5%	95%
Cash	$348,764	$178,470	51.17%	($229,901)	$1,105,669	$72,690	$663,226
Cash / Futures	$331,572	$174,141	52.52%	($180,696)	$1,102,676	$57,777	$632,236
Cash / Options	$350,829	$179,129	51.06%	($113,989)	$1,143,000	$71,183	$667,622
Futures	$314,029	$152,336	48.51%	($126,202)	$1,057,723	$70,141	$563,835
Futures / Cash	$317,191	$154,042	48.56%	($178,706)	$1,032,958	$70,109	$570,833
Futures / Options	$317,894	$154,022	48.45%	($122,000)	$1,085,848	$70,693	$568,225
Options	$345,575	$171,280	49.56%	($130,917)	$1,281,272	$78,594	$638,300
Options / Cash	$344,934	$171,298	49.66%	($191,353)	$1,228,382	$79,332	$634,458
Options / Futures	$325,904	$165,490	50.78%	($142,815)	$1,217,868	$70,574	$607,326

Hedging of at least one commodity occurred in 4,990 of the 5,000 iterations for this simulation. As shown in the table below, doubling the volatility significantly increased the average total risk management costs for all marketing strategies although the costs among marketing strategies maintained their cost levels proportional to one another.

Table 25. Simulation 2 - Low Debt Farm – Marketing Strategy Total Risk Management Costs

Marketing Strategy	Total Risk Management Costs: Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$81,354	$47,766	58.7%	$417,435
Cash / Options	$37,052	$14,678	39.6%	$95,110
Futures	$313,702	$161,819	51.6%	$1,077,283
Futures / Cash	$256,369	$144,731	56.5%	$1,024,803
Futures / Options	$293,421	$155,113	52.9%	$1,072,039
Options	$208,357	$81,269	39.0%	$517,866
Options / Cash	$171,305	$67,383	39.3%	$436,800
Options / Futures	$252,659	$106,398	42.1%	$800,955

Table 26. Simulation 2 – Low Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

Marketing Strategy	Differences from Cash Strategy Results: Average Net Farm Income	Standard Deviation	Range	90% Interval	Returns: Standard Deviation Difference from Cash
Cash / Futures	($17,192)	($4,328)	($52,199)	($16,077)	5.32%
Cash / Options	$2,065	$659	($78,581)	$5,902	-1.78%
Futures	($34,735)	($26,133)	($151,644)	($96,842)	8.33%
Futures / Cash	($31,573)	($24,428)	($123,906)	($89,813)	9.53%
Futures / Options	($30,870)	($24,447)	($127,722)	($93,005)	8.33%
Options	($3,189)	($7,190)	$76,619	($30,831)	3.45%
Options / Cash	($3,830)	($7,171)	$84,165	($35,411)	4.19%
Options / Futures	($22,860)	($12,979)	$25,113	($53,785)	5.14%

In the table below, the “Cash / Options” combination on average has the lowest total costs as it did in the initial simulation for the low debt farm. Once again, the futures based strategies carry the highest average and maximum costs as well as the highest skewness, pointing to a higher probability of high costs.

Table 27. Simulation 2 – Low Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,985	4,985	4,990	4,990	4,990	4,990	4,990	4,990
Mean	$81,599	$37,164	$314,331	$256,883	$294,009	$208,774	$171,648	$253,165
Std. Dev.	$47,629	$14,559	$161,370	$144,420	$154,711	$80,813	$67,012	$105,901
Median	$73,785	$36,658	$290,191	$232,955	$270,120	$205,355	$168,480	$246,286
5%	$18,147	$13,973	$92,577	$66,153	$85,221	$82,483	$67,416	$92,023
95%	$171,353	$62,166	$618,779	$532,503	$588,731	$347,513	$287,520	$437,338
Minimum	$5,000	$2,100	$12,000	$12,000	$12,000	$5,760	$5,760	$5,760
Maximum	$417,435	$95,110	$1,077,283	$1,024,803	$1,072,039	$517,866	$436,800	$800,955
Skew	0.98	0.24	0.84	0.99	0.89	0.24	0.27	0.4
Kurtosis	1.5	-0.13	0.89	1.3	1.03	-0.22	-0.18	0.06

Again, the strategies employing the use of options allow for the highest average differences above the cash marketing strategy. In contrast, the use of futures contracts is typically associated with higher total costs on average. Across all marketing strategies, the effect of doubling the volatility parameter was to nearly double the total costs of risk management as compared to the baseline simulation. These results are presented in the table on the following page.

Table 28. Simulation 2 – Low Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($28,309)	$95,695	$11,029	$45,468
Cash / Options	($12,561)	$36,844	$19,626	$37,550
Futures	($87,676)	$366,434	$55,486	$225,056
Futures / Cash	($85,774)	$308,194	$55,226	$174,281
Futures / Options	($86,874)	$344,882	$57,838	$213,010
Options	($64,852)	$210,563	$78,951	$206,381
Options/ Cash	($63,366)	$173,547	$77,448	$169,042
Options / Futures	($75,967)	$261,419	$73,547	$238,098

As was the case in the baseline simulation, the cash marketing strategy requires the least amount of additional borrowing and thus provides the highest average and maximum percent change in equity. The average total operating line borrowed refers to the annual sum of the monthly borrowings against the operating line. Other values reported in this and complementary operating line tables in other simulations refer to the amount remaining on the operating line at the end of the year. Both average and maximum values are reported for this liability. Additional information related to the calculations for borrowings and payments against the operating line are provided in Chapter III of this thesis.

Table 29. Simulation 2– Low Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$125,676	$34,814	$739,988
Cash / Futures	$236,563	$58,329	$788,787
Cash / Options	$190,117	$45,987	$781,057
Futures	$1,136,263	$289,598	$1,249,723
Futures / Cash	$873,183	$204,967	$1,139,900
Futures / Options	$1,076,688	$260,311	$1,196,665
Options	$990,025	$172,017	$982,011
Options / Cash	$764,398	$128,776	$940,444
Options / Futures	$1,056,800	$214,452	$989,741

Table 30. Simulation 2 – Low Debt Farm – Percent Change in Equity

Marketing Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	8.4%	-1.7%	21.6%
Cash / Futures	7.2%	-3.1%	20.6%
Cash / Options	7.8%	-3.4%	20.9%
Futures	3.1%	-5.7%	15.4%
Futures / Cash	4.1%	-4.5%	16.3%
Futures / Options	3.4%	-6.2%	15.5%
Options	4.7%	-6.2%	17.9%
Options / Cash	5.4%	-4.9%	18.7%
Options / Futures	4.1%	-6.5%	17.3%

In the previous tables, a similar pattern as found in the baseline simulation was shown with the use of futures typically ranking the highest for those measures related to variance reduction while options and cash strategies typically allow for higher net farm income levels.

Low Debt – 50% Milk Production Hedged Simulation

The third and final simulation for the low debt farm returned all of the parameter to the values of the baseline simulation. The level milk production hedged was then adjusted such that only 50% of the annual milk production was hedged. This change tests whether comparable ranges of net farm income and reductions in net farm income variance can be achieved with lower amounts of capital invested in risk management tools.

The prices generated in this simulation are again similar to the historical prices as well as the baseline simulation. Exceptions were on the upside where some milk prices generated were a bit higher than those found in the baseline simulation. Hedging occurred in 4,858 iterations of the total 5,000 iterations of this simulation.

Table 31. Simulation 3 – Low Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.35	$8.69	$27.79	$2.75	$1.90	$22.78	$191.72	$141.28	$408.96
February	$12.28	$8.63	$30.65	$2.75	$1.83	$20.58	$191.74	$118.47	$373.07
March	$12.35	$7.05	$31.18	$2.75	$1.68	$21.44	$191.75	$113.82	$383.20
April	$12.46	$8.22	$26.02	$2.82	$1.52	$15.18	$195.29	$110.97	$673.25
May	$12.66	$7.62	$45.19	$2.82	$1.52	$14.61	$195.24	$95.09	$706.76
June	$12.98	$7.82	$43.06	$2.91	$1.51	$49.48	$208.22	$98.64	$881.50
July	$13.35	$7.94	$67.89	$2.91	$1.46	$47.20	$208.24	$86.92	$837.98
August	$13.60	$8.09	$41.11	$3.02	$1.34	$12.25	$210.16	$74.65	$955.40
September	$13.92	$7.81	$43.51	$3.02	$1.32	$12.06	$207.67	$90.47	$775.98
October	$13.60	$7.59	$40.47	$2.81	$1.40	$16.99	$201.27	$48.57	$902.17
November	$13.18	$7.02	$33.68	$2.81	$1.24	$15.94	$202.30	$80.01	$973.83
December	$13.01	$6.84	$64.04	$2.81	$1.25	$16.32	$202.34	$76.58	$1,038.88

Table 32. Simulation 3 – Low Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	188	$16.96	$26.95	$15.65
	2	336	$16.04	$28.62	$14.65
	3	526	$16.02	$31.25	$14.65
	4	980	$15.23	$24.54	$13.84
	5	1,065	$15.81	$47.03	$13.79
	6	1,090	$16.38	$43.59	$14.57
	7	1,495	$13.57	$38.56	$8.17
	8	1,822	$13.89	$31.37	$8.94
	9	2,208	$13.56	$36.91	$8.65
	10	1,859	$15.89	$40.12	$14.51
	11	1,598	$15.73	$35.12	$14.36
	12	1,472	$15.87	$71.75	$14.38
Corn	2	292	$2.66	$7.27	$1.94
	3	477	$2.62	$5.05	$19.20
	4	974	$2.70	$8.48	$1.68
	5	1,055	$2.70	$6.18	$1.58
	6	1,039	$2.78	$9.66	$1.89
	7	1,421	$2.77	$8.36	$1.84
	8	1,733	$2.87	$10.01	$1.59
	9	2,126	$2.86	$9.59	$1.58
	10	1,808	$2.68	$8.32	$1.56
	11	1,549	$2.70	$9.59	$1.50
	12	1,432	$2.68	$8.46	$1.39
Soybean Meal	2	292	$190.68	$318.42	$143.38
	3	477	$190.89	$318.91	$132.05
	4	974	$197.53	$565.22	$128.80
	5	1,055	$196.24	$617.31	$124.42
	6	1,039	$201.79	$542.61	$118.89
	7	1,421	$204.33	$651.33	$97.91
	8	1,733	$207.75	$576.49	$104.48
	9	2,126	$204.35	$602.99	$118.15
	10	1,808	$198.67	$611.77	$73.41
	11	1,549	$199.02	$649.95	$90.70
	12	1,432	$198.35	$656.68	$102.87

The results of this simulation point towards comparable levels of net farm income with the baseline simulation. In addition, net farm income was reduced by comparable levels in both absolute dollar amounts and in reduction of the coefficient of variation. Finally, this approach is equivalent to using a partial cash marketing strategy in conjunction with all other risk management strategies thus leaving open the possibility of a wider range in net farm income.

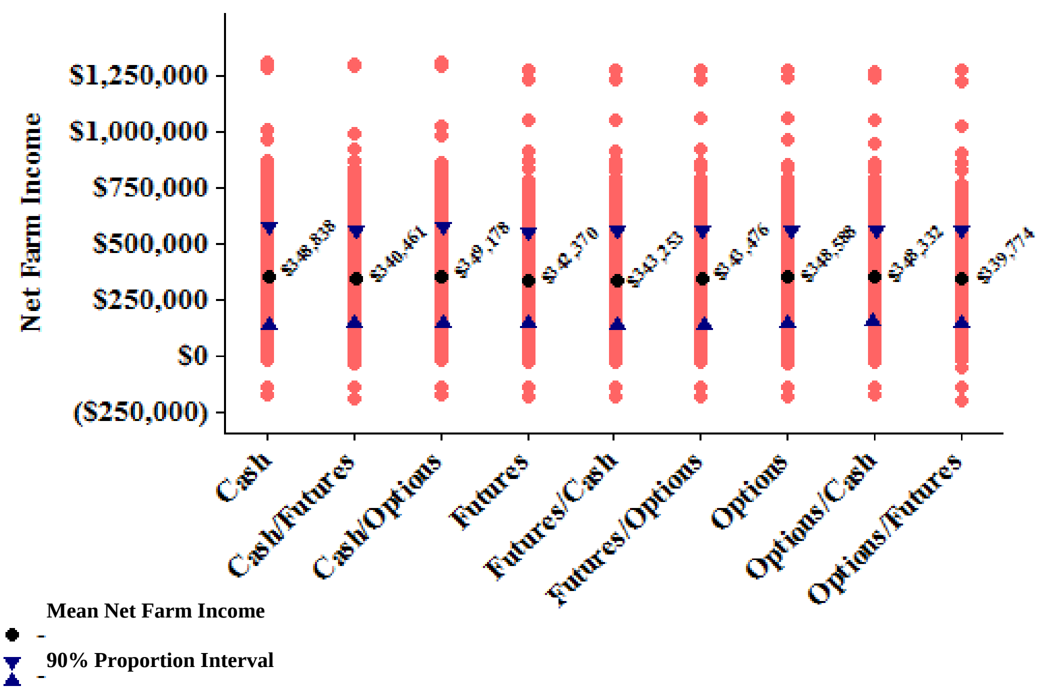

Figure 7. Simulation 3 – Low Debt Farm – Net Farm Income

As shown in the table below the average net farm income achieved by hedging only 50% of milk production is comparable to the levels of net farm income achieved using full hedging. In addition, the range of outcomes for net farm income was much wider, although the extreme values on the high side are likely due to the outlying milk price generated in this simulation. Examination of comparable simulations for the remaining debt levels may yield more insight as to the performance of this approach.

Table 33. Simulation 3 – Low Debt Farm – Net Farm Income Summary

Marketing Strategy	Average	Standard Deviation	C.V.	Minimum	Maximum	5%	95%
Cash	$348,838	$130,357	37.37%	($176,480)	$1,304,661	$152,414	$575,368
Cash / Futures	$340,461	$127,161	37.35%	($193,728)	$1,293,658	$148,659	$559,829
Cash / Options	$349,178	$130,469	37.36%	($179,531)	$1,304,344	$153,281	$575,832
Futures	$342,370	$124,797	36.45%	($187,920)	$1,270,911	$150,972	$554,205
Futures / Cash	$343,253	$125,126	36.45%	($184,023)	$1,269,668	$152,156	$555,377
Futures / Options	$343,476	$125,206	36.45%	($187,141)	$1,273,690	$151,491	$556,016
Options	$348,588	$128,002	36.72%	($184,111)	$1,271,230	$152,156	$566,868
Options / Cash	$348,332	$127,870	36.71%	($181,031)	$1,267,366	$152,977	$567,143
Options / Futures	$339,774	$124,539	36.65%	($200,996)	$1,271,819	$148,343	$552,004

In terms of cost and returns, the total costs of hedging are reduced significantly due to reducing the hedge ratio on milk production. However the reduction is not linear as average and maximum costs were only reduced by about two-thirds.

Table 34. Simulation 3 - Low Debt Farm – Marketing Strategy Total Risk Management Costs

Marketing Strategy	Total Risk Management Costs			
	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,426	$25,480	66.3%	$185,021
Cash / Options	$12,812	$6,809	53.1%	$39,064
Futures	$78,110	$45,272	58.0%	$337,238
Futures / Cash	$51,497	$33,211	64.5%	$266,075
Futures / Options	$64,309	$38,682	60.2%	$299,995
Options	$42,029	$22,038	52.4%	$126,126
Options / Cash	$29,217	$15,522	53.1%	$102,240
Options / Futures	$67,643	$38,811	57.4%	$264,030

Table 35. Simulation 3 – Low Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Marketing Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($8,376)	($3,196)	$6,245	($11,784)	8.32%
Cash / Options	$340	$112	$2,734	($403)	-0.87%
Futures	($6,467)	($5,560)	($22,310)	($19,720)	7.12%
Futures / Cash	($5,584)	($5,231)	($27,449)	($19,733)	10.16%
Futures / Options	($5,362)	($5,151)	($20,310)	($18,429)	8.01%
Options	($249)	($2,355)	($25,800)	($8,242)	5.60%
Options / Cash	($506)	($2,486)	($32,744)	($8,787)	8.51%
Options / Futures	($9,063)	($5,818)	($8,326)	($19,294)	8.60%

Observation of the risk management cost statistics below shows a definite reduction across all strategies by hedging only half of the milk production. However, this reduction in cost should be judged in the context of other measures as well, such as variance reduction. While hedging only half as much milk production may reduce costs, it may not meet some other goal such as providing as much downside protection as full hedging would. Again this is another example of the impact the preferences of a decision maker will have on the final selection of marketing strategies. While some producers may prefer the reduced variance associated with full hedging, others may be willing to risk some downside protection in the hopes of achieving higher upsides while at the same time spending less in total with a reduced hedging ratio.

Table 36. Simulation 3 – Low Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,816	4,816	4,858	4,858	4,858	4,858	4,858	4,858
Mean	$39,894	$13,301	$80,393	$53,002	$66,188	$43,257	$30,071	$69,620
Standard Deviation	$24,809	$6,452	$43,886	$32,488	$37,625	$21,136	$14,909	$37,586
Median	$35,790	$12,755	$74,172	$47,311	$60,289	$41,625	$28,800	$65,473
5%	$7,062	$3,793	$20,036	$11,245	$15,385	$12,309	$8,400	$16,038
95%	$86,962	$24,758	$160,574	$114,430	$135,571	$80,140	$56,160	$136,375
Minimum	$5,000	$140	$6,000	$6,000	$6,000	$720	$720	$720
Maximum	$185,021	$39,064	$337,238	$266,075	$299,995	$126,126	$102,240	$264,030
Skew	1.02	0.47	0.81	1.05	0.92	0.49	0.56	0.72
Kurtosis	1.41	-0.03	0.77	1.54	1.13	0.04	0.21	0.61

Comparing the performance of the reduced hedge ratio to the baseline simulation based on relative net farm income values above or below the cash marketing strategy again points to both advantages and disadvantages for reducing the hedge ratio. In favor of reducing the hedge ratio are the facts that on average total risk management costs will decrease and the average differences below the cash marketing strategy are not as low as those found with full hedging in the baseline simulation. On the other hand, the average value above the cash marketing strategy is lower with the reduced hedging ratio. These results are due to the cash market exposure maintained across all marketing strategies with less than full hedging. Thus, when market prices move in an unfavorable way with regard to a hedge, and vice versa, there still remains cash market exposure to balance the negative or positive effects. One drawback to this cash market exposure though is the fact that the range in negative net farm income values was actually greater than the baseline simulation. Thus this marketing plan still leaves open the upside potential of the cash marketing strategy but with the drawback of less downside protection.

Table 37. Simulation 3 – Low Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	Average Difference Below	Average Total Risk Management Costs	Average Difference Above	Average Total Risk Management Costs
Cash / Futures	($12,520)	$46,278	$3,897	$20,443
Cash / Options	($4,545)	$13,107	$6,977	$13,563
Futures	($18,082)	$91,914	$12,274	$61,660
Futures / Cash	($16,887)	$63,228	$11,670	$37,300
Futures / Options	($17,684)	$75,958	$13,260	$51,342
Options	($13,252)	$42,861	$18,354	$43,827
Options/ Cash	($12,150)	$29,759	$17,494	$30,558
Options / Futures	($19,622)	$72,937	$15,857	$61,629

Related to the reduced costs of hedging in this simulation is the reduced need for additional operating line funds. Thus this approach leads to slightly higher average percent changes in equity. Again for this simulation the cash marketing strategy allows for the greatest average and potential changes in equity while the “Cash / Options” and “Options / Cash” strategies ranked second and third in this measure as shown below.

Table 38. Simulation 3 – Low Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$73,799	$14,261	$717,732
Cash / Futures	$113,608	$19,746	$760,959
Cash / Options	$88,581	$15,787	$733,200
Futures	$207,097	$29,515	$819,047
Futures / Cash	$140,994	$21,848	$789,108
Futures / Options	$172,900	$25,038	$805,057
Options	$143,819	$21,306	$762,944
Options / Cash	$116,125	$18,686	$746,995
Options / Futures	$182,595	$27,202	$790,703

Table 39. Simulation 3 – Low Debt Farm – Percent Change in Equity

Marketing Strategy	% Change in Equity – Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	8.4%	-0.7%	25.1%
Cash / Futures	7.8%	-1.1%	24.4%
Cash / Options	8.2%	-0.8%	24.7%
Futures	7.1%	-1.2%	23.6%
Futures / Cash	7.6%	-1.1%	24.0%
Futures / Options	7.4%	-1.1%	23.8%
Options	7.7%	-0.8%	24.3%
Options / Cash	7.9%	-0.8%	24.5%
Options / Futures	7.3%	-1.2%	24.1%

Interestingly, in the tables above, the strategies based on options generally provided the largest reduction in net farm income range. This is in contrast to the other simulations for the low debt farm where futures contracts typically provide the highest returns on this measure. This should be interpreted carefully though as this reduced range differed from the strategies based on futures contracts by only a few thousand dollars. In addition, this minimal range associated with options also means that the options did not provide the higher upside in net farm income as would be expected.

Summary of Low Debt Farm

In general, the low debt farm appears to enjoy some benefits of market risk management in terms of reduced variation in net farm income, but to a lesser extent on average than either the average or high debt farms as will be shown. In general, the low debt farm gains a much smaller benefit in terms of the variance reduction as a percentage of expected net farm income while at the same time facing total risk management costs comparable to the average and high debt farms.

Average Debt Farm

Identical simulations as were run for the low debt farm were completed for the average debt farm. Due to the increased debt payments associated with the average and high debt farms, the marketing triggers increased in value. Therefore in order for hedging to be initiated, a higher margin must be presented by the market. These increased debt payments and marketing triggers represent the only fundamental difference in the structure of the model between the low debt farm and the high debt farm. Results of the simulations for the average debt are presented in this section.

Average Debt Farm – Baseline Simulation

The baseline simulation for the average debt farm is identical to the baseline simulation for the low debt farm with the exception of the marketing triggers. Due to the increased debt obligations of the average debt farm the marketing trigger to meet all cash flow obligations increased by $.63 to $12.52. Market prices and hedged prices generated within this simulation are shown below.

Table 40. Simulation 4 – Average Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.36	$8.77	$29.84	$2.75	$1.89	$19.97	$191.71	$139.09	$360.54
February	$12.28	$8.54	$29.49	$2.75	$1.69	$20.04	$191.71	$123.55	$366.37
March	$12.35	$7.78	$30.26	$2.75	$1.67	$19.24	$191.69	$111.42	$384.23
April	$12.46	$8.22	$23.14	$2.82	$1.59	$24.68	$195.28	$106.81	$1,219.04
May	$12.66	$8.23	$40.62	$2.83	$1.49	$23.12	$195.28	$106.18	$1,256.73
June	$12.98	$8.11	$49.51	$2.91	$1.48	$50.04	$208.31	$95.97	$724.68
July	$13.34	$7.35	$35.54	$2.91	$1.30	$52.26	$208.32	$81.79	$770.41
August	$13.60	$7.44	$38.47	$3.02	$1.36	$20.13	$210.27	$86.32	$908.70
September	$13.91	$7.83	$39.83	$3.02	$1.28	$19.54	$207.88	$89.90	$710.13
October	$13.60	$7.32	$40.78	$2.82	$1.25	$76.80	$201.14	$53.66	$890.70
November	$13.18	$7.42	$35.74	$2.82	$1.23	$80.57	$202.25	$66.84	$1,043.48
December	$13.01	$7.23	$73.96	$2.82	$1.22	$78.21	$202.26	$66.18	$1,029.70

Table 41. Simulation 4-Average Debt Farm-Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	186	$16.97	$29.14	$15.65
	2	331	$16.05	$29.87	$14.66
	3	537	$16.00	$32.29	$14.56
	4	932	$15.29	$23.42	$13.52
	5	1,074	$15.78	$42.34	$13.81
	6	1,088	$16.40	$48.48	$14.61
	7	1,516	$13.55	$30.22	$9.09
	8	1,850	$13.94	$35.53	$9.55
	9	2,186	$13.62	$30.36	$9.48
	10	1,890	$15.88	$38.81	$14.43
	11	1,562	$15.74	$37.16	$14.51
	12	1,455	$15.88	$58.67	$14.41
Corn	2	300	$2.65	$6.16	$1.91
	3	469	$2.66	$6.05	$1.92
	4	927	$2.71	$5.81	$1.91
	5	1,069	$2.75	$8.63	$1.59
	6	1,029	$2.76	$7.28	$1.83
	7	1,450	$2.79	$14.16	$1.65
	8	1,768	$2.85	$8.57	$1.53
	9	2,120	$2.83	$10.31	$1.45
	10	1,829	$2.69	$7.02	$1.57
	11	1,525	$2.70	$9.25	$1.50
	12	1,402	$2.68	$7.49	$1.24
Soybean Meal	2	300	$192.75	$343.34	$139.09
	3	469	$189.45	$343.34	$120.17
	4	927	$197.77	$1,208.02	$118.77
	5	1,069	$195.57	$491.29	$114.23
	6	1,029	$205.15	$570.04	$115.79
	7	1,450	$206.13	$570.04	$107.55
	8	1,768	$208.07	$659.63	$108.74
	9	2,120	$206.55	$613.48	$108.78
	10	1,829	$196.73	$560.12	$71.37
	11	1,525	$199.22	$589.59	$102.63
	12	1,402	$199.14	$610.46	$102.16

As can be seen in the graph and table below, the cash marketing strategy provided the highest average and maximum net farm income levels in the baseline simulation for the average debt farm. As would be expected with increased leverage, the range of potential net farm income values is wider though some of this can be explained by the outlying value of corn in the month of December, which drove net farm income down.

In line with what would be predicted the strategies employing the use of futures contract on milk prices, the primary driver of net farm income, reduced variance in net farm income. Those strategies using options to hedge milk prices allowed for greater upside potential in net farm income while at the same time reducing variance in net farm income.

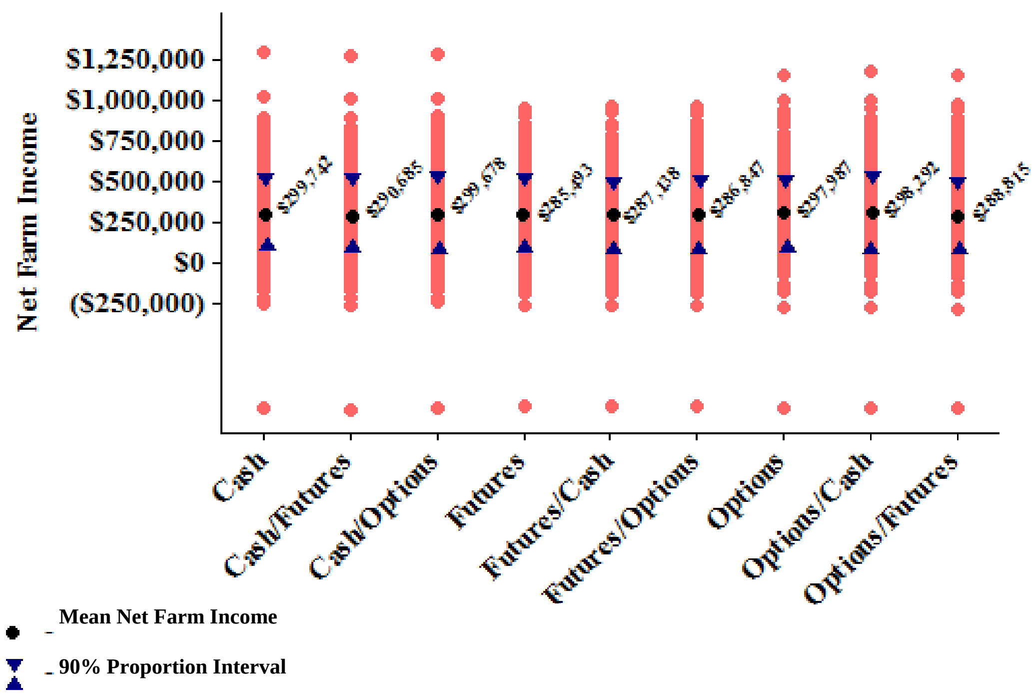

Figure 8. Simulation 4 – Average Debt Farm – Net Farm Income

As shown below, the average net farm income of all hedging strategies was roughly $7,000 less than the cash marketing strategy. In addition, hedging strategies succeeded in reducing the coefficient of variation by about 1%.

Table 42. Simulation 4 – High Debt Farm – Net Farm Income Summary

Marketing Strategy	Average	Standard Deviation	C.V.	Minimum	Maximum	5%	95%
Cash	$299,742	$135,104	45.07%	($910,212)	$1,294,010	$95,899	$530,040
Cash / Futures	$290,685	$131,799	45.34%	($916,138)	$1,269,652	$91,595	$513,846
Cash / Options	$299,678	$135,278	45.14%	($907,937)	$1,276,035	$96,258	$528,901
Futures	$285,493	$125,876	44.09%	($896,506)	$952,431	$97,428	$499,578
Futures / Cash	$287,138	$126,511	44.06%	($897,846)	$963,735	$97,562	$501,863
Futures / Options	$286,847	$126,502	44.10%	($895,575)	$956,580	$97,562	$502,852
Options	$297,987	$132,487	44.46%	($900,063)	$1,153,033	$101,195	$522,425
Options / Cash	$298,292	$132,471	44.41%	($902,334)	$1,169,063	$100,092	$521,146
Options / Futures	$288,815	$128,748	44.58%	($908,580)	$1,146,541	$97,340	$504,614

Analyzing the returns of using the various risk management tools reveals that only the “Futures / Cash” tool combination yielded positive returns on average. However this combination of tools also had the second highest average total costs. In addition, the maximum total risk management costs of those tool combinations using futures to price milk were nearly twice the amount associated with the combinations using options for the same purpose.

Table 43. Simulation 4 - Average Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Marketing Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,340	$25,324	66.1%	$236,064
Cash / Options	$12,752	$6,831	53.6%	$40,120
Futures	$128,330	$78,113	60.9%	$678,950
Futures / Cash	$101,745	$66,469	65.3%	$614,832
Futures / Options	$114,497	$71,879	62.8%	$644,484
Options	$70,991	$37,451	52.8%	$218,772
Options / Cash	$58,239	$30,970	53.2%	$189,120
Options / Futures	$96,580	$53,016	54.9%	$362,304

Table 44. Simulation 4 – Average Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($9,057)	($3,305)	($18,432)	($11,890)	8.62%
Cash / Options	($64)	$174	($20,250)	($1,498)	-1.37%
Futures	($14,264)	($9,228)	($355,284)	($31,992)	7.19%
Futures / Cash	($12,618)	($8,593)	($342,641)	($29,841)	8.45%
Futures / Options	($12,909)	($8,603)	($352,067)	($28,851)	7.51%
Options	($1,770)	($2,617)	($151,126)	($12,912)	3.69%
Options / Cash	($1,465)	($2,633)	($132,825)	($13,087)	4.52%
Options / Futures	($10,943)	($6,356)	($149,101)	($26,867)	6.58%

In the table below, the total risk management costs across all marketing tool combinations does not differ markedly on average from the low debt farm baseline simulation. In addition, despite the increase in value of the marketing trigger, the number of iterations in which hedging occurred also did not change tremendously.

Table 45. Simulation 4 – Average Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,823	4,823	4,855	4,855	4,855	4,855	4,855	4,855
Mean	$39,748	$13,220	$132,163	$104,784	$117,917	$73,111	$59,979	$99,464
Standard Deviation	$24,676	$6,495	$76,009	$65,052	$70,127	$35,909	$29,723	$51,066
Median	$35,684	$12,550	$119,600	$92,628	$105,543	$69,522	$56,640	$94,048
5%	$7,642	$3,772	$30,563	$21,258	$25,820	$20,806	$16,800	$26,600
95%	$86,409	$24,814	$274,579	$228,934	$250,145	$138,458	$114,720	$192,603
Minimum	$5,000	$152	$12,000	$12,000	$12,000	$960	$960	$960
Maximum	$236,064	$40,120	$678,950	$614,832	$644,484	$218,772	$189,120	$362,304
Skew	1.09	0.51	0.94	1.08	1.01	0.52	0.55	0.63
Kurtosis	2.03	-0.05	1.28	1.82	1.53	-0.04	0.03	0.26

Further analysis shows that the combinations using options to hedge milk price allow for higher overall returns at generally lower costs. The combination "Options / Futures" is an exception to this statement as the costs incurred caused its returns to drop.

Table 46. Simulation 4 – Average Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	Average Difference Below	Average Total Risk Management Costs	Average Difference Above	Average Total Risk Management Costs
Cash / Futures	($13,207)	$45,326	$3,484	$20,551
Cash / Options	($4,864)	$12,913	$6,624	$13,680
Futures	($37,226)	$154,186	$21,809	$95,373
Futures / Cash	($35,959)	$126,117	$21,908	$71,317
Futures / Options	($36,562)	$139,090	$22,459	$84,323
Options	($26,791)	$73,259	$33,246	$72,893
Options/ Cash	($25,791)	$60,086	$33,519	$59,815
Options / Futures	($33,334)	$102,263	$30,539	$93,906

Table 47. Simulation 4– Average Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line – Average	End of Year Operating Line - Maximum
Cash	$452,601	$140,584	$1,980,859
Cash / Futures	$578,754	$177,843	$2,010,814
Cash / Options	$507,660	$154,170	$1,991,054
Futures	$995,867	$311,121	$2,042,049
Futures / Cash	$872,566	$267,738	$2,022,808
Futures / Options	$940,646	$290,045	$2,033,472
Options	$820,411	$231,163	$2,030,950
Options / Cash	$740,290	$209,865	$2,020,287
Options / Futures	$900,474	$264,583	$2,051,199

Table 48. Simulation 4 – High Debt Farm – Percent Change in Equity

Marketing Strategy	% Change in Equity – Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	9.7%	-16.6%	31.4%
Cash / Futures	9.0%	-17.2%	30.1%
Cash / Options	9.5%	-16.9%	30.9%
Futures	7.0%	-18.1%	20.5%
Futures / Cash	7.6%	-17.7%	21.8%
Futures / Options	7.3%	-18.0%	21.3%
Options	8.1%	-17.8%	27.9%
Options / Cash	8.4%	-17.6%	28.4%
Options / Futures	7.6%	-18.2%	27.1%

With respect to the total additional liabilities taken on in this simulation, the cash marketing strategy required the least amount of additional borrowing and thus resulted in the highest percent change in equity followed by the "Cash / Options" and "Cash / Futures" strategies.

Average Debt Farm – Doubled Volatility Simulation

The doubled volatility simulation for the average debt farm uses the same assumptions and parameters as the baseline simulation with the exception of the volatility parameter, which is doubled. Prices generated using these parameters fall in line with historical data and the baseline simulation prices on average with some outlying values for milk prices and soybean meal. As is the case with the analysis of any simulation, outputs should be analyzed in the context of the inputs used to generate them and not simply analyzed based on absolute levels.

Table 49. Simulation 5 – Average Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.36	$8.15	$27.77	$2.75	$1.86	$18.08	$191.69	$134.91	$371.96
February	$12.28	$7.70	$32.68	$2.75	$1.48	$18.02	$191.68	$97.80	$428.20
March	$12.35	$6.34	$38.41	$2.75	$1.30	$18.29	$191.67	$82.12	$502.46
April	$12.45	$6.51	$25.44	$2.83	$1.14	$14.48	$195.42	$72.36	$1,000.84
May	$12.67	$6.72	$102.10	$2.83	$1.17	$17.47	$195.62	$59.87	$1,382.41
June	$12.98	$5.95	$48.69	$2.90	$0.87	$27.83	$208.44	$56.44	$945.66
July	$13.35	$5.79	$61.50	$2.90	$0.90	$28.11	$208.43	$49.45	$1,037.90
August	$13.59	$5.66	$50.02	$3.02	$0.73	$14.03	$211.73	$36.36	$1,673.51
September	$13.91	$5.58	$44.17	$3.02	$0.62	$14.49	$208.28	$46.01	$1,120.00
October	$13.60	$5.75	$40.25	$2.81	$0.57	$30.00	$200.59	$21.07	$1,548.83
November	$13.17	$4.96	$47.99	$2.81	$0.50	$30.49	$202.33	$32.24	$1,165.10
December	$13.03	$4.24	$45.22	$2.81	$0.52	$30.75	$202.41	$28.51	$1,246.51

Table 50. Simulation - Average Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	252	$16.68	$29.56	$15.65
	2	520	$15.72	$37.05	$14.55
	3	988	$15.59	$33.44	$14.53
	4	1,412	$15.02	$23.59	$13.82
	5	1,604	$15.43	$113.13	$13.61
	6	1,759	$15.92	$50.61	$14.35
	7	2,366	$13.60	$48.45	$6.50
	8	2,652	$13.83	$36.42	$6.20
	9	3,060	$13.57	$31.64	$6.11
	10	2,728	$15.68	$40.89	$14.17
	11	2,476	$15.52	$41.64	$14.23
	12	2,366	$15.59	$50.78	$14.23
Corn	2	405	$2.69	$7.50	$1.79
	3	767	$2.62	$5.33	$1.66
	4	1,379	$2.67	$7.04	$1.41
	5	1,546	$2.73	$10.48	$1.42
	6	1,632	$2.74	$8.22	$1.39
	7	2,253	$2.78	$12.90	$1.31
	8	2,549	$2.87	$13.71	$1.20
	9	3,000	$2.89	$11.30	$1.02
	10	2,655	$2.71	$9.43	$1.11
	11	2,410	$2.67	$7.53	$0.94
	12	2,301	$2.68	$12.38	$0.96
Soybean Meal	2	405	$186.34	$321.14	$109.18
	3	767	$190.19	$352.03	$98.79
	4	1,379	$197.55	$895.78	$87.23
	5	1,546	$198.18	$579.07	$91.16
	6	1,632	$203.86	$649.73	$67.71
	7	2,253	$206.48	$736.13	$66.62
	8	2,549	$209.51	$807.32	$60.16
	9	3,000	$204.98	$664.21	$49.55
	10	2,655	$197.18	$1,178.53	$31.92
	11	2,410	$200.24	$825.27	$64.07
	12	2,301	$197.13	$667.98	$58.13

As shown in the graph and table below, the high milk price generated for the month of May likely resulted in the outlying net farm income value seen across all marketing strategies. The “Cash / Options” strategy provided the highest average net farm income while the “Options / Cash” allowed for the highest potential net farm income.

The strategies employing futures contracts to price milk succeeded in reducing the coefficient of variation by one to two percent. Interestingly the “Cash / Futures” strategy actually increased the coefficient of variation above the cash marketing strategy however this is likely due to the higher upside results of the strategy. Outlying points on the following figure are due to the extremely high price generated for the May milk contract within this simulation.

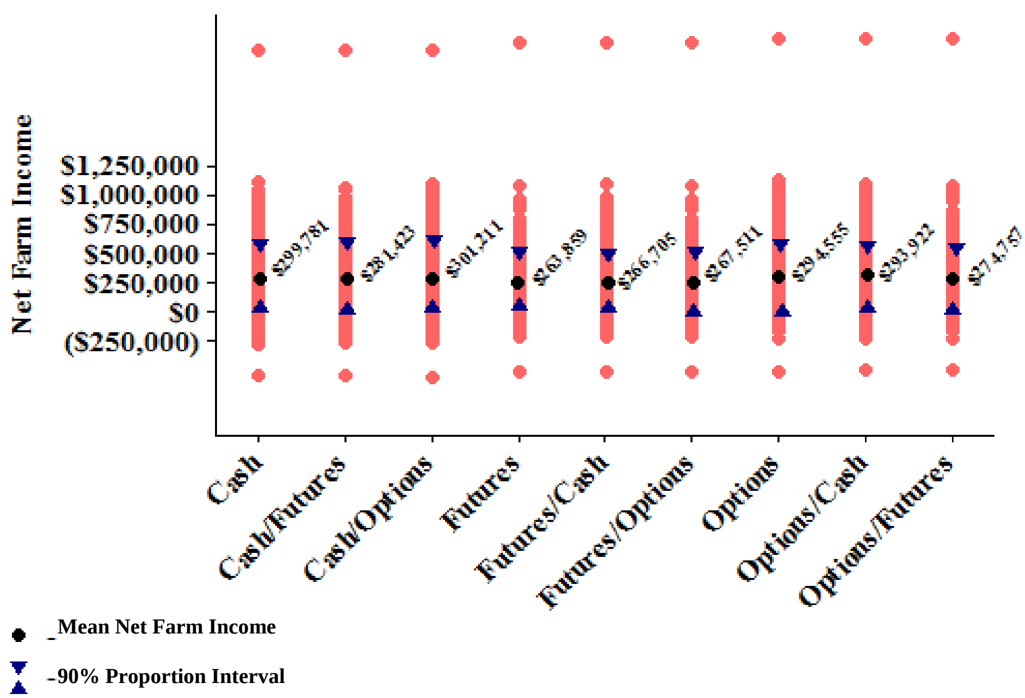

Figure 9. Simulation 5 – Average Debt Farm – Net Farm Income

Table 51. Simulation 5 – Average Debt Farm – Net Farm Income Summary

	Average	*Standard Deviation*	*C.V.*	*Minimum*	*Maximum*	*5%*	*95%*
Cash	$299,781	$176,340	58.82%	($561,440)	$2,241,526	$38,757	$602,828
Cash / Futures	$281,423	$172,301	61.23%	($563,496)	$2,238,110	$20,652	$579,007
Cash / Options	$301,211	$176,741	58.68%	($568,181)	$2,236,100	$37,642	$601,050
Futures	$263,859	$150,763	57.14%	($528,146)	$2,314,981	$30,555	$509,529
Futures / Cash	$266,705	$152,370	57.13%	($521,486)	$2,309,556	$30,723	$517,475
Futures / Options	$267,511	$152,263	56.92%	($528,246)	$2,304,337	$33,687	$518,521
Options	$294,555	$168,115	57.07%	($517,055)	$2,337,325	$37,041	$575,039
Options / Cash	$293,922	$168,229	57.24%	($510,127)	$2,342,681	$39,367	$569,193
Options / Futures	$274,757	$162,895	59.29%	($512,370)	$2,339,487	$25,560	$543,286

As can be seen in the above table the risk management tools performed as would be predicted with futures contracts generally reducing variance and options allowing for higher upside potential. In addition, the use of options not only allowed for higher upside potential but also increased the minimum net farm income thus shifting the range of outcomes upward.

Similar to the low debt farm, the "Cash / Options" and "Futures / Cash" strategies presented the only positive returns. Those strategies using futures contracts to price milk had the highest associated costs. Once again these costs nearly doubled as compared to the baseline simulation.

Table 52. Simulation 5 - Average Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Marketing Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$81,225	$46,258	57.0%	$350,079
Cash / Options	$36,813	$14,175	38.5%	$98,590
Futures	$310,048	$159,105	51.3%	$1,225,638
Futures / Cash	$253,282	$142,606	56.3%	$1,116,218
Futures / Options	$290,095	$152,472	52.6%	$1,171,798
Options	$206,973	$78,405	37.9%	$510,298
Options / Cash	$170,160	$65,069	38.2%	$444,480
Options / Futures	$251,385	$102,361	40.7%	$688,479

Table 53. Simulation 5 – Average Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Marketing Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($18,358)	($4,039)	($1,359)	($5,716)	4.97%
Cash / Options	$1,429	$401	$1,316	($663)	-1.09%
Futures	($35,937)	($25,577)	$40,161	($85,098)	8.25%
Futures / Cash	($33,090)	($23,970)	$28,076	($77,319)	9.46%
Futures / Options	($32,284)	($24,077)	$29,617	($79,237)	8.30%
Options	($5,237)	($8,225)	$51,414	($26,073)	3.97%
Options / Cash	($5,869)	($8,111)	$49,842	($34,245)	4.77%
Options / Futures	($25,033)	($13,445)	$48,892	($46,345)	5.35%

The following table illustrates the costs associated with the various risk management tool combinations. Similar to the low debt farm, the total risk management costs more than doubled in relation to the increased volatility of this simulation as compared to the baseline simulation.

Table 54. Simulation 5 – Average Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,987	4,987	4,992	4,992	4,992	4,992	4,992	4,992
Mean	$81,437	$36,909	$310,545	$253,688	$290,560	$207,305	$170,433	$251,788
Std. Dev.	$46,131	$14,069	$158,747	$142,359	$152,151	$78,029	$64,764	$101,947
Median	$75,472	$36,252	$288,924	$229,699	$267,301	$203,749	$167,520	$245,453
5%	$19,470	$15,163	$92,314	$66,034	$85,108	$85,214	$69,600	$96,039
95%	$166,787	$61,031	$610,855	$521,019	$577,221	$340,716	$280,320	$433,698
Minimum	$5,000	$1,104	$18,894	$12,000	$14,886	$8,160	$8,160	$8,160
Maximum	$350,079	$98,590	$1,225,638	$1,116,218	$1,171,798	$510,298	$444,480	$688,479
Skew	0.91	0.26	0.85	0.99	0.9	0.25	0.28	0.37
Kurtosis	1.23	-0.17	0.93	1.34	1.07	-0.15	-0.07	-0.01

In terms of absolute differences above the cash marketing net farm income, those strategies using options to price milk outperformed all others as shown in the table below.

Table 55. Simulation 5 – Average Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($28,439)	$93,714	$11,470	$44,731
Cash / Options	($12,588)	$36,256	$19,684	$37,764
Futures	($88,322)	$361,042	$54,071	$223,442
Futures / Cash	($85,964)	$303,633	$53,656	$171,435
Futures / Options	($87,739)	$339,849	$56,038	$211,765
Options	($65,531)	$208,617	$76,631	$205,517
Options/ Cash	($63,670)	$171,970	$74,369	$168,291
Options / Futures	($76,639)	$258,300	$71,341	$239,574

As would be predicted, the cash marketing strategy was associated with the lowest average total new borrowings, which translates to the highest percent change in equity. On average the percent change in equity was much lower across all marketing strategies in this simulation due to the increased liabilities.

Table 56. Simulation 5 – Average Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$463,186	$156,688	$1,263,117
Cash / Futures	$677,055	$227,658	$1,270,868
Cash / Options	$603,500	$190,970	$1,272,606
Futures	$1,425,693	$553,996	$1,431,874
Futures / Cash	$1,294,740	$474,052	$1,389,223
Futures / Options	$1,412,350	$529,186	$1,428,639
Options	$1,415,144	$431,859	$1,320,309
Options / Cash	$1,246,560	$371,319	$1,310,071
Options / Futures	$1,418,004	$477,256	$1,318,572

Table 57. Simulation 5 – Average Debt Farm – Percent Change in Equity

Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	9.7%	-9.0%	52.1%
Cash / Futures	8.1%	-9.2%	50.1%
Cash / Options	8.9%	-9.2%	50.8%
Futures	3.0%	-10.4%	38.6%
Futures / Cash	4.3%	-10.1%	40.4%
Futures / Options	3.5%	-10.3%	39.2%
Options	5.0%	-10.8%	39.7%
Options / Cash	5.9%	-10.7%	40.9%
Options / Futures	4.2%	-10.8%	39.0%

For this simulation, options based strategies provide both the most downside protection as well as allow for the highest upside potential. However, despite the higher costs, the use of futures strategies in general still provide the highest returns based on the measures provided in this work.

Average Debt Farm – 50% Milk Production Hedged Simulation

This simulation uses all parameters and assumptions of the baseline simulation for the average debt farm however the hedge ratio on milk production is decreased to 50%. Market prices and hedged prices generated in this simulation are comparable to historical data at the average level and are generally comparable to the prices generated in the baseline simulation for this farm. Maximum corn prices in this simulation are not as high as those generated in the baseline simulation.

Table 58. Simulation 6 – Average Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.36	$9.03	$40.62	$2.75	$1.88	$17.17	$191.71	$139.58	$376.98
February	$12.28	$8.41	$29.71	$2.75	$1.67	$16.00	$191.76	$121.83	$409.56
March	$12.35	$8.05	$46.90	$2.75	$1.50	$15.73	$191.79	$110.52	$389.13
April	$12.45	$8.34	$23.70	$2.82	$1.49	$13.10	$195.38	$106.94	$718.35
May	$12.66	$8.06	$39.14	$2.82	$1.47	$14.07	$195.38	$94.47	$652.45
June	$12.98	$7.62	$51.30	$2.91	$1.56	$23.48	$208.22	$93.16	$752.12
July	$13.35	$7.75	$39.94	$2.91	$1.47	$23.42	$208.19	$81.68	$776.15
August	$13.60	$7.73	$39.26	$3.01	$1.33	$16.39	$209.95	$79.63	$1,101.00
September	$13.91	$7.45	$39.73	$3.01	$1.25	$14.80	$207.81	$81.85	$742.36
October	$13.60	$8.08	$50.82	$2.82	$1.38	$43.11	$201.34	$48.81	$949.82
November	$13.18	$7.34	$32.83	$2.82	$1.33	$44.41	$202.06	$66.38	$730.68
December	$13.01	$7.58	$50.00	$2.82	$1.25	$45.19	$201.99	$63.44	$818.75

Table 59. Simulation 6 – Average Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	181	$17.06	$39.39	$15.65
	2	324	$16.07	$29.25	$14.55
	3	542	$16.04	$51.42	$14.59
	4	964	$15.25	$22.33	$13.93
	5	1,074	$15.78	$39.52	$13.94
	6	1,062	$16.43	$56.36	$14.51
	7	1,517	$13.62	$30.96	$8.71
	8	1,775	$13.95	$33.27	$8.78
	9	2,171	$13.64	$44.56	$8.90
	10	1,824	$15.92	$44.56	$14.49
	11	1,551	$15.75	$35.38	$14.43
	12	1,469	$15.85	$44.01	$14.47
Corn	2	284	$2.65	$4.97	$1.96
	3	485	$2.64	$5.23	$1.92
	4	962	$2.70	$6.49	$1.74
	5	1,069	$2.73	$7.06	$1.55
	6	1,008	$2.76	$7.93	$1.73
	7	1,451	$2.77	$11.06	$1.64
	8	1,708	$2.85	$9.42	$1.48
	9	2,083	$2.86	$13.57	$1.52
	10	1,777	$2.70	$7.32	$1.49
	11	1,509	$2.72	$8.00	$1.51
	12	1,420	$2.70	$8.02	$1.50
Soybean Meal	2	284	$189.60	$397.04	$136.21
	3	485	$187.84	$318.19	$142.98
	4	962	$195.84	$486.81	$123.94
	5	1,069	$198.16	$599.68	$121.31
	6	1,008	$203.86	$515.99	$100.09
	7	1,451	$206.17	$653.39	$121.00
	8	1,708	$206.30	$558.47	$99.83
	9	2,083	$206.54	$719.11	$100.70
	10	1,777	$198.54	$768.67	$83.51
	11	1,509	$201.01	$546.32	$103.53
	12	1,420	$200.26	$616.77	$82.42

The cash marketing strategy resulted in the highest average net farm income with the “Cash / Options” and “Options / Cash” strategies close behind. Once again the use of futures contracts successfully reduced the variance in net farm income. Variance reductions resulting from a 50% hedge ratio on milk were comparable to those resulting from a full hedge. The cash marketing strategy also provided the greatest upside potential in net farm income. Only slight shifts occurred in the minimum values of net farm income between the cash marketing strategy and the various hedging strategies. These results can be seen in the graph and table on the following page.

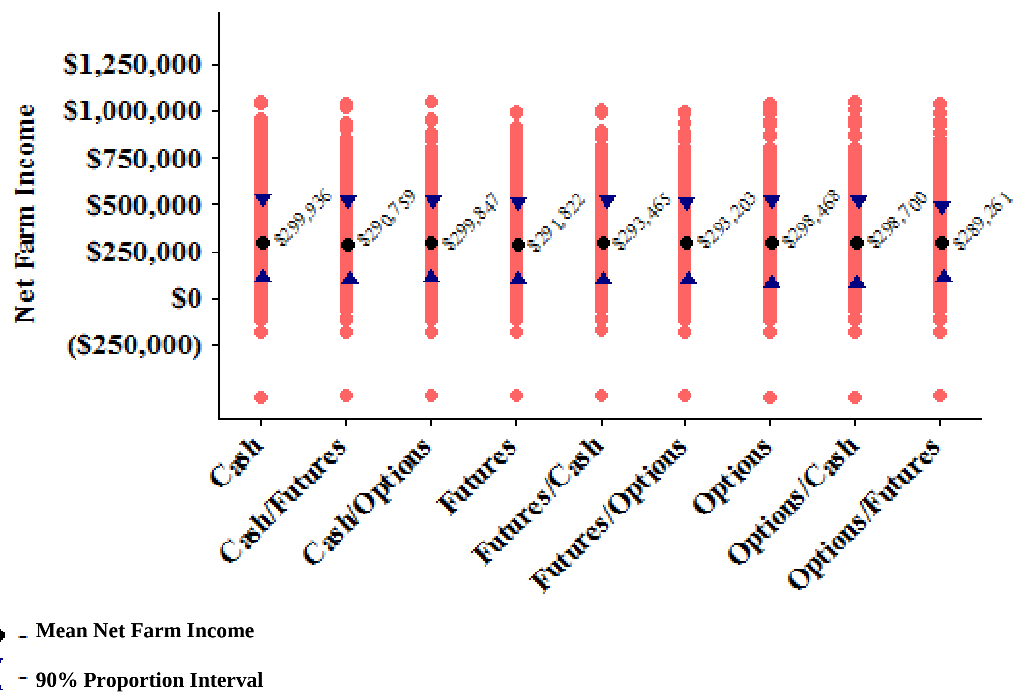

Figure 10. Simulation 6 – Average Debt Farm – Net Farm Income

Table 60. Simulation 6 – Average Debt Farm – Net Farm Income Summary

	Average	*Standard Deviation*	*C.V.*	*Minimum*	*Maximum*	*5%*	*95%*
Cash	$299,936	$130,520	43.52%	($532,783)	$1,052,591	$103,849	$527,145
Cash / Futures	$290,759	$127,198	43.75%	($531,221)	$1,042,147	$100,096	$507,543
Cash / Options	$299,847	$130,704	43.59%	($531,813)	$1,049,463	$105,898	$526,041
Futures	$291,822	$124,788	42.76%	($528,977)	$999,265	$102,414	$506,399
Futures / Cash	$293,465	$125,339	42.71%	($530,620)	$1,002,106	$103,123	$507,541
Futures / Options	$293,203	$125,355	42.75%	($529,675)	$998,977	$103,646	$508,190
Options	$298,468	$128,627	43.10%	($532,897)	$1,040,520	$104,555	$520,111
Options / Cash	$298,700	$128,576	43.05%	($533,842)	$1,043,649	$104,810	$519,688
Options / Futures	$289,261	$124,940	43.19%	($531,676)	$1,033,204	$101,367	$502,617

All hedging strategies in this simulation had negative returns on average. The least negative return was generated using the "Futures / Cash" strategy. The lowest returns were associated with the "Cash / Futures" and "Options / Futures" strategies.

Table 61. Simulation 6 - Average Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Marketing Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,331	$25,666	67.0%	$197,987
Cash / Options	$12,696	$6,900	54.3%	$40,356
Futures	$77,260	$45,213	58.5%	$270,810
Futures / Cash	$50,733	$33,009	65.1%	$218,274
Futures / Options	$63,429	$38,655	60.9%	$235,204
Options	$41,669	$22,273	53.5%	$133,652
Options / Cash	$28,973	$15,656	54.0%	$94,080
Options / Futures	$67,304	$39,104	58.1%	$263,267

As shown in the tables on the following page, the results of the reduced hedging ratio simulation nearly match those of the baseline simulation. One exception is that of the top ranked tool combination as measured by the reduction in the 90%

confidence interval, which for this simulation was the "Options / Futures" combination. However this combination also had the second highest costs on average.

Table 62. Simulation 6 – Average Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($9,177)	($3,322)	($12,006)	($15,849)	8.67%
Cash / Options	($89)	$184	($4,098)	($3,153)	-1.45%
Futures	($8,118)	($5,732)	($57,132)	($19,310)	7.42%
Futures / Cash	($6,474)	($5,181)	($52,649)	($18,878)	10.21%
Futures / Options	($6,736)	($5,165)	($56,722)	($18,752)	8.14%
Options	($1,471)	($1,893)	($11,957)	($7,740)	4.54%
Options / Cash	($1,239)	($1,944)	($7,883)	($8,418)	6.71%
Options / Futures	($10,677)	($5,581)	($20,494)	($22,046)	8.29%

The table below illustrates the range in costs associated with the various risk management tool combinations. Again, the use of options in a strategy tends to yield a more compact distribution of costs than does the use of futures contracts.

Table 63. Simulation 6 – Average Debt Farm - Descriptive Statistics of Risk Management Tool Expenses

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,795	4,795	4,821	4,821	4,821	4,821	4,821	4,821
Mean	$39,970	$13,239	$80,129	$52,616	$65,784	$43,216	$30,048	$69,802
Std. Dev.	$24,928	$6,516	$43,477	$32,109	$37,346	$21,158	$14,896	$37,569
Median	$35,607	$12,616	$74,581	$47,121	$60,332	$41,240	$28,560	$64,748
5%	$7,139	$3,812	$20,149	$10,970	$15,725	$12,916	$8,880	$16,818
95%	$86,720	$24,808	$160,936	$114,929	$136,930	$80,768	$56,880	$138,540
Minimum	$5,000	$308	$6,000	$6,000	$6,000	$240	$240	$240
Maximum	$197,987	$40,356	$270,810	$218,274	$235,204	$133,652	$94,080	$263,267
Skew	1.04	0.52	0.77	1.01	0.87	0.51	0.56	0.73
Kurtosis	1.53	-0.01	0.48	1.17	0.75	-0.03	0.07	0.53

Similar to the low debt farm, the average differences above and below the cash marketing strategy were reduced by two-thirds to one-half as compared to the baseline simulation as shown in the following table.

Table 64. Simulation 6 – Average Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($13,457)	$45,707	$3,666	$19,925
Cash / Options	($4,946)	$12,950	$6,515	$13,667
Futures	($19,026)	$90,188	$10,689	$61,235
Futures / Cash	($17,570)	$61,843	$10,602	$37,254
Futures / Options	($18,514)	$74,368	$11,525	$51,377
Options	($14,194)	$42,949	$16,381	$43,620
Options/ Cash	($13,002)	$29,852	$15,879	$30,357
Options / Futures	($21,105)	$73,642	$13,990	$59,672

Table 65. Simulation 6 – Average Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$449,418	$139,355	$1,294,722
Cash / Futures	$572,291	$174,515	$1,300,884
Cash / Options	$501,489	$151,403	$1,297,490
Futures	$778,666	$228,836	$1,311,966
Futures / Cash	$645,763	$191,465	$1,305,466
Futures / Options	$715,755	$208,986	$1,308,734
Options	$646,921	$184,990	$1,307,207
Options / Cash	$577,646	$168,886	$1,303,939
Options / Futures	$729,231	$214,578	$1,309,633

Table 66. Simulation 6 – Average Debt Farm – Percent Change in Equity

Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	9.7%	-8.4%	26.1%
Cash / Futures	9.0%	-8.6%	25.3%
Cash / Options	9.5%	-8.5%	25.9%
Futures	8.1%	-8.8%	23.3%
Futures / Cash	8.7%	-8.7%	24.0%
Futures / Options	8.4%	-8.8%	23.8%
Options	8.8%	-8.7%	24.7%
Options / Cash	9.1%	-8.6%	25.0%
Options / Futures	8.3%	-8.7%	24.0%

The cash marketing strategy was associated with the lowest amount of new borrowings and subsequently the highest percent change in equity on average. The highest maximum amount of new borrowings was associated with the “Futures” strategy, which corresponds to the lowest minimum percent change in equity for this simulation.

High Debt Farm

Comparable simulations as were run for the low and average debt farms were run for the high debt farm. All parameters were held constant across these debt levels with the exception of the marketing triggers, which due to the additional debt obligations of the high debt farm increased to $13.87.

High Debt – Baseline Simulation

The market and hedge prices generated in this simulation are presented below. In general the average prices generated for each commodity are comparable to both historical data and to the other simulations in this work. Maximum prices generated for milk contracts in June and December are nearly twice the level of the other months.

Table 67. Simulation 7 – High Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.35	$8.94	$29.35	$2.75	$1.86	$23.80	$191.70	$138.38	$369.22
February	$12.28	$8.27	$27.14	$2.75	$1.75	$23.01	$191.72	$120.98	$367.85
March	$12.35	$8.05	$28.81	$2.75	$1.68	$25.08	$191.65	$112.32	$404.93
April	$12.45	$8.18	$24.32	$2.82	$1.58	$11.53	$195.23	$104.66	$690.80
May	$12.66	$7.75	$38.54	$2.82	$1.41	$12.00	$195.26	$104.77	$655.55
June	$12.98	$7.75	$74.52	$2.90	$1.56	$21.53	$208.32	$100.20	$760.85
July	$13.35	$7.90	$45.76	$2.91	$1.50	$21.27	$208.30	$94.84	$711.42
August	$13.61	$7.45	$34.45	$3.02	$1.22	$21.14	$210.24	$95.65	$922.75
September	$13.91	$7.51	$35.61	$3.02	$1.30	$20.44	$207.86	$77.85	$898.38
October	$13.60	$7.56	$37.78	$2.81	$1.24	$21.69	$201.06	$57.35	$807.01
November	$13.19	$7.20	$40.84	$2.81	$1.11	$21.09	$202.20	$82.89	$727.75
December	$13.02	$7.04	$73.42	$2.81	$1.03	$22.06	$202.25	$82.61	$842.31

Table 68. Simulation 7 – High Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	185	$16.96	$27.69	$15.65
	2	330	$16.06	$28.50	$14.65
	3	549	$15.98	$31.45	$14.68
	4	951	$15.26	$24.87	$13.80
	5	1,079	$15.79	$39.91	$13.90
	6	1,087	$16.41	$63.14	$14.55
	7	1,514	$13.55	$28.88	$8.92
	8	1,801	$13.90	$27.38	$7.95
	9	2,163	$13.59	$26.64	$9.33
	10	1,853	$15.90	$41.94	$14.41
	11	1,567	$15.73	$31.96	$14.41
	12	1,492	$15.87	$71.66	$14.44
Corn	2	297	$2.70	$6.11	$1.96
	3	478	$2.64	$6.62	$1.90
	4	947	$2.70	$5.93	$1.78
	5	1,074	$2.73	$7.54	$1.70
	6	1,003	$2.78	$10.56	$1.85
	7	1,452	$2.80	$10.25	$1.72
	8	1,729	$2.87	$9.54	$1.53
	9	2,100	$2.85	$8.57	$1.50
	10	1,795	$2.69	$7.32	$1.43
	11	1,516	$2.68	$6.45	$1.46
	12	1,445	$2.69	$8.06	$1.54
Soybean Meal	2	297	$194.23	$319.31	$144.29
	3	478	$187.80	$369.22	$112.92
	4	947	$197.50	$484.45	$121.05
	5	1,074	$198.34	$647.24	$122.59
	6	1,003	$204.82	$475.47	$123.54
	7	1,452	$206.23	$652.59	$113.66
	8	1,729	$208.07	$596.14	$155.31
	9	2,100	$206.95	$584.38	$113.50
	10	1,795	$196.90	$626.95	$87.93
	11	1,516	$200.74	$795.44	$93.88
	12	1,445	$200.47	$683.20	$101.64

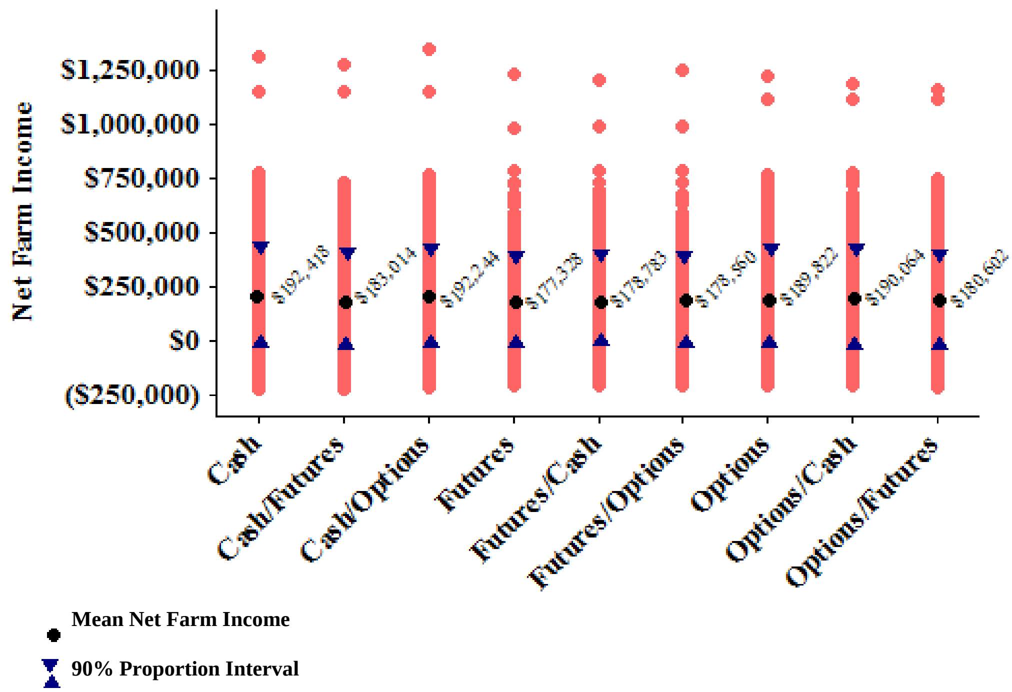

Figure11. Simulation 7 – High Debt Farm – Net Farm Income

Based on the graph and table on the following page the cash marketing strategy presented the highest average net farm income. The "Cash / Options" strategy allowed for the greatest upside potential while the "Options" strategy provided the most downside protection. Those strategies employing the use of futures contracts in pricing milk reduced the coefficient of variation by about 1%.

Table 69. Simulation 7 – High Debt Farm – Net Farm Income Summary

	Average	*Standard Deviation*	*C.V.*	*Minimum*	*Maximum*	*5%*	*95%*
Cash	$192,418	$134,058	69.67%	($226,311)	$1,305,646	($12,126)	$421,234
Cash / Futures	$183,014	$130,312	71.20%	($230,471)	$1,275,869	($13,864)	$403,748
Cash / Options	$192,244	$133,988	69.70%	($224,353)	$1,344,316	($10,942)	$422,063
Futures	$177,328	$123,566	69.68%	($215,031)	$1,225,124	($11,956)	$387,920
Futures / Cash	$178,783	$124,211	69.48%	($215,886)	$1,203,816	($10,916)	$391,448
Futures / Options	$178,560	$124,151	69.53%	($213,961)	$1,242,220	($11,323)	$390,719
Options	$189,822	$130,748	68.88%	($212,671)	$1,222,282	($8,387)	$418,614
Options / Cash	$190,064	$130,812	68.83%	($214,595)	$1,183,879	($7,308)	$416,897
Options / Futures	$180,602	$127,071	70.36%	($218,812)	$1,153,919	($12,105)	$400,280

The strategy with the least negative return was the “Futures / Cash” combination which had the third highest costs on average but also provided the highest maximum return. Hedging occurred in 4,835 of the 5,000 iterations of this simulation.

Table 70. Simulation 7 - High Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,564	$25,716	66.7%	$193,407
Cash / Options	$12,744	$6,882	54.0%	$42,860
Futures	$128,690	$78,968	61.4%	$546,001
Futures / Cash	$102,171	$67,091	65.7%	$455,180
Futures / Options	$114,915	$72,572	63.2%	$490,068
Options	$70,910	$37,859	53.4%	$262,768
Options / Cash	$58,166	$31,322	53.8%	$232,800
Options / Futures	$96,730	$53,967	55.8%	$367,081

Table 71. Simulation 7 – High Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($9,404)	($3,746)	($25,617)	($15,748)	9.71%
Cash / Options	($173)	($70)	$36,713	($355)	0.55%
Futures	($15,085)	($10,491)	($91,802)	($33,484)	8.15%
Futures / Cash	($13,631)	($9,846)	($112,254)	($30,996)	9.64%
Futures / Options	($13,852)	($9,907)	($75,776)	($31,319)	8.62%
Options	($2,582)	($3,310)	($97,004)	($6,359)	4.67%
Options / Cash	($2,342)	($3,245)	($133,483)	($9,154)	5.58%
Options / Futures	($11,804)	($6,987)	($159,226)	($20,975)	7.22%

The table on the following page offers summary statistics on the total risk management costs for the baseline simulation of the high debt farm. On average the total risk management costs for the high debt farm are comparable to those for the low and average debt farm. In addition, the number of iterations in which hedging occurred is also comparable despite the marketing trigger increasing in value. In general, those marketing tool combinations employing futures contracts have higher costs on average and have higher positive skew. In addition, the higher kurtosis points to the occurrence of relatively large deviations from the average total cost associated with the use of futures contracts.

Table 72. Simulation 7 – High Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,816	4,816	4,837	4,837	4,837	4,837	4,837	4,837
Mean	$40,037	$13,231	$133,026	$105,614	$118,788	$73,300	$60,126	$99,990
Standard Deviation	$25,051	$6,537	$76,611	$65,492	$70,598	$36,145	$29,937	$51,813
Median	$35,916	$12,567	$120,152	$93,211	$106,005	$69,046	$56,640	$94,290
5%	$6,993	$3,832	$32,473	$23,763	$27,431	$21,828	$17,760	$27,163
95%	$86,233	$25,128	$278,397	$231,818	$252,731	$138,534	$114,240	$192,537
Minimum	$5,000	$248	$12,000	$12,000	$12,000	$960	$960	$960
Maximum	$193,407	$42,860	$546,001	$455,180	$490,068	$262,768	$232,800	$367,081
Skew	0.94	0.54	0.89	1.02	0.95	0.55	0.59	0.65
Kurtosis	1.06	0.07	0.76	1.14	0.95	0.08	0.18	0.34

Based upon the relative returns, the “Futures” based strategy provided the least negative return when net farm income was below the cash marketing strategy level while the “Options / Cash” based strategy provided the highest return when net farm income was above the cash marketing strategy level.

Table 73. Simulation 7 – High Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($13,852)	$46,348	$3,257	$19,113
Cash / Options	($4,991)	$13,122	$6,242	$13,391
Futures	($38,206)	$154,777	$21,525	$95,405
Futures / Cash	($37,004)	$126,678	$21,507	$71,123
Futures / Options	($37,706)	$139,824	$22,216	$84,131
Options	($27,315)	$73,578	$33,006	$72,863
Options/ Cash	($26,375)	$60,528	$32,847	$59,485
Options / Futures	($33,937)	$102,823	$30,257	$94,037

Table 74. Simulation 7 – High Debt Farm – Operating Line Borrowed

Marketing Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$923,264	$595,121	$1,227,578
Cash / Futures	$951,255	$632,398	$1,286,469
Cash / Options	$943,314	$609,769	$1,246,777
Futures	$1,043,798	$729,204	$1,476,451
Futures / Cash	$1,018,537	$701,265	$1,423,330
Futures / Options	$1,033,635	$715,224	$1,443,136
Options	$1,027,121	$675,385	$1,377,931
Options / Cash	$1,007,835	$660,783	$1,358,125
Options / Futures	$1,027,603	$697,075	$1,417,784

Table 75. Simulation 7 – High Debt Farm – Percent Change in Equity

Marketing Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	17.0%	-2.5%	68.7%
Cash / Futures	15.3%	-3.2%	63.0%
Cash / Options	16.4%	-2.7%	66.3%
Futures	11.0%	-8.0%	54.6%
Futures / Cash	12.3%	-6.2%	58.0%
Futures / Options	11.7%	-7.3%	55.5%
Options	13.5%	-8.1%	57.7%
Options / Cash	14.2%	-7.0%	60.1%
Options / Futures	12.5%	-9.5%	56.5%

The cash marketing strategy provided the highest average percent change in equity followed by the “Cash / Options” strategy at 16.4%. Percent changes in equity will generally increase as debt levels increase due to the fact that the starting equity is much lower. The highest average and maximum operating line funds borrowed were associated with the “Futures” strategy in this simulation. As would be expected, the total borrowings against the operating line increased as the debt level increased.

High Debt Farm – Doubled Volatility Simulation

Similar to the simulations performed for the low and average debt farms, this simulation for the high debt farm maintains all baseline parameters with the exception of the volatility parameter which is doubled. Market and hedged prices generated in this simulation are shown in the following tables. Prices are generally in line with historical data and other simulations. Outlying values did occur in the August and October contracts for soybean meal.

Table 76. Simulation 8 – High Debt – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.36	$8.33	$40.21	$2.75	$1.83	$27.50	$191.72	$132.62	$371.10
February	$12.28	$8.18	$26.23	$2.75	$1.44	$25.84	$191.75	$101.04	$438.47
March	$12.35	$6.99	$43.28	$2.75	$1.27	$28.06	$191.78	$81.75	$454.67
April	$12.46	$7.24	$24.89	$2.82	$1.09	$13.38	$194.99	$61.53	$1,152.39
May	$12.66	$6.50	$39.23	$2.82	$0.97	$12.06	$195.01	$55.53	$1,231.00
June	$12.98	$5.76	$68.60	$2.90	$0.84	$22.16	$208.31	$46.40	$907.85
July	$13.35	$5.55	$41.50	$2.90	$0.89	$19.65	$208.08	$48.00	$974.42
August	$13.60	$6.12	$56.29	$3.01	$0.76	$18.39	$210.36	$44.33	$1,744.75
September	$13.91	$5.42	$48.95	$3.01	$0.74	$23.28	$207.67	$31.84	$1,289.85
October	$13.60	$6.00	$43.72	$2.81	$0.73	$32.16	$201.49	$19.67	$2,077.20
November	$13.19	$4.81	$40.65	$2.81	$0.62	$31.47	$201.90	$40.81	$1,045.99
December	$13.00	$4.02	$51.57	$2.81	$0.58	$31.41	$201.79	$31.34	$1,166.03

Table 77. Simulation 8- High Debt – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	261	$16.67	$37.37	$15.65
	2	527	$15.66	$27.66	$14.51
	3	965	$15.60	$31.57	$14.50
	4	1,402	$15.03	$23.24	$13.88
	5	1,598	$15.37	$39.41	$13.11
	6	1,790	$15.93	$60.69	$14.43
	7	2,320	$13.57	$34.46	$6.71
	8	2,714	$13.92	$41.83	$6.04
	9	3,020	$13.61	$47.28	$7.27
	10	2,766	$15.67	$47.28	$14.30
	11	2,466	$15.53	$36.44	$14.34
	12	2,388	$15.59	$41.33	$14.21
Corn	2	403	$2.58	$4.81	$1.64
	3	783	$2.62	$8.23	$1.68
	4	1,361	$2.72	$7.69	$1.53
	5	1,561	$2.72	$8.47	$1.33
	6	1,654	$2.75	$7.68	$1.14
	7	2,200	$2.78	$10.72	$1.19
	8	2,602	$2.89	$11.20	$1.05
	9	2,939	$2.88	$8.86	$0.79
	10	2,687	$2.71	$8.34	$1.10
	11	2,402	$2.71	$13.83	$0.99
	12	2,317	$2.67	$10.26	$0.94
Soybean Meal	2	403	$192.30	$317.36	$130.61
	3	783	$189.30	$374.57	$109.09
	4	1,361	$197.39	$583.29	$88.26
	5	1,561	$198.84	$1,224.52	$78.55
	6	1,654	$205.50	$662.17	$81.07
	7	2,200	$203.70	$674.46	$59.51
	8	2,602	$206.70	$638.09	$61.48
	9	2,939	$204.91	$823.05	$72.56
	10	2,687	$196.37	$1,016.93	$25.04
	11	2,402	$199.14	$1,235.30	$58.79
	12	2,317	$200.57	$935.31	$57.01

Based on the graph and table presented on the following page, the "Cash / Options" strategy provided the highest net farm income on average. However the cash marketing approach still allowed for the highest maximum net farm income. Interestingly the "Options" and "Options / Cash" strategies provided the greatest reductions in the coefficient of variation. However this could have been a result of the lower maximum net farm income values associated with these strategies as compared to the extremely high maximum net farm income values associated with the cash marketing strategy. In essence the "Options" and "Options / Cash" strategies did not have as wide of a standard deviation due to their associated upside potential being lower than what would be expected as options based strategies tend to track a bit closer to cash based strategies.

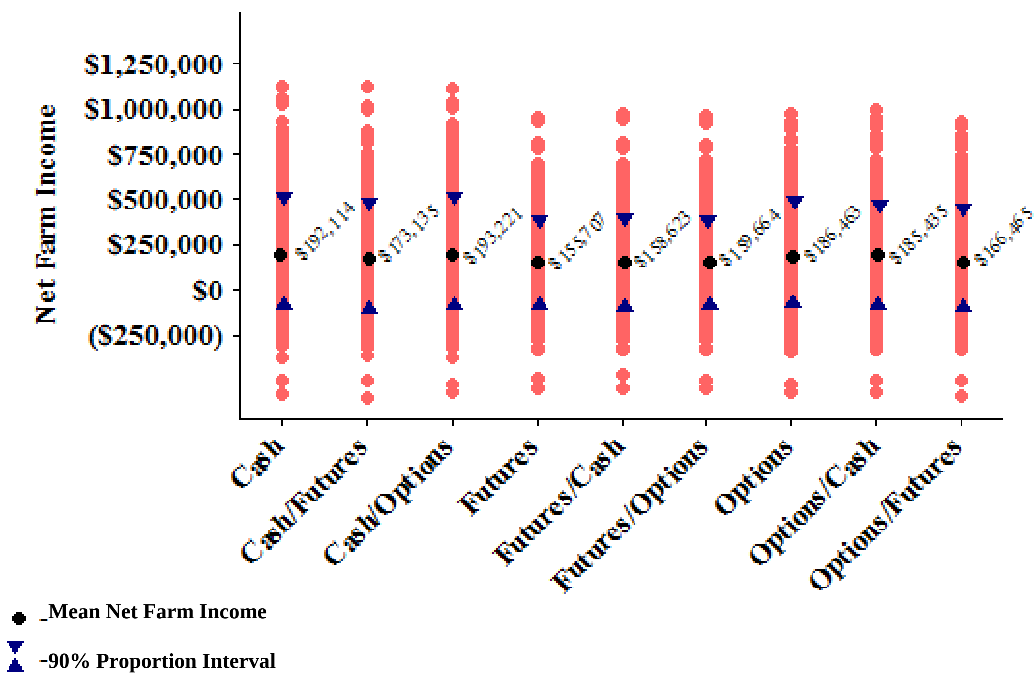

Figure 12. Simulation 8 – High Debt Farm – Net Farm Income

Table 78. Simulation 8 – High Debt Farm – Net Farm Income Summary

	Average	*Standard Deviation*	*C.V.*	*Minimum*	*Maximum*	*5%*	*95%*
Cash	$192,114	$177,917	92.61%	($575,390)	$1,116,571	($82,769)	$499,612
Cash / Futures	$173,135	$173,042	99.95%	($594,847)	$1,115,482	($97,382)	$463,880
Cash / Options	$193,221	$177,980	92.11%	($571,495)	$1,114,340	($80,081)	$499,587
Futures	$155,707	$149,926	96.29%	($541,689)	$948,617	($79,366)	$404,000
Futures / Cash	$158,623	$151,366	95.43%	($550,231)	$973,767	($79,149)	$407,108
Futures / Options	$159,664	$151,419	94.84%	($546,537)	$958,137	($76,503)	$410,342
Options	$186,463	$167,079	89.60%	($561,786)	$975,878	($70,778)	$473,966
Options / Cash	$185,435	$166,804	89.95%	($565,479)	$991,508	($72,126)	$471,024
Options / Futures	$166,465	$161,672	97.12%	($585,137)	$925,383	($84,995)	$439,402

The "Cash / Options" and "Futures / Cash" provided the highest returns, which were both positive. However the "Futures / Cash" strategy had associated costs nearly nine times greater than the "Cash / Options" strategy on average.

Table 79. Simulation 8 - High Debt Farm – Marketing Strategy Total Risk Management Costs

	Total Risk Management Costs			
Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$81,409	$47,223	58.0%	$315,212
Cash / Options	$36,869	$14,489	39.3%	$83,690
Futures	$310,905	$158,942	51.1%	$1,158,308
Futures / Cash	$253,782	$142,226	56.0%	$1,101,005
Futures / Options	$290,651	$152,452	52.5%	$1,156,259
Options	$207,459	$80,360	38.7%	$565,972
Options / Cash	$170,591	$66,671	39.1%	$504,000
Options / Futures	$251,999	$105,228	41.8%	$782,789

Table 80. Simulation 8 – High Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

	Differences from Cash Strategy Results				Returns
Strategy	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($18,992)	($4,875)	$18,367	($21,119)	5.99%
Cash / Options	$1,096	$63	($6,126)	($2,713)	-0.17%
Futures	($36,391)	($27,990)	($201,656)	($99,015)	9.00%
Futures / Cash	($33,467)	($26,550)	($167,963)	($96,124)	10.46%
Futures / Options	($32,437)	($26,498)	($187,286)	($95,536)	9.12%
Options	($5,638)	($10,837)	($154,298)	($37,636)	5.22%
Options / Cash	($6,655)	($11,113)	($134,974)	($39,231)	6.51%
Options / Futures	($25,638)	($16,245)	($181,441)	($57,984)	6.45%

Similar to both the low and average debt farms, the total risk management costs more than doubled for the high debt for the doubled volatility simulation. Coupled with this, the 90% confidence interval for the high debt farm also more than doubled itself. This result could be interpreted as the relative consistency of risk management performance regardless of the volatility in the market. In other words, the tools had a linear effectiveness as volatility increased. This relationship could be partially explained by the absence of a trend factor in generating prices for this model. However, it is important to note this consistent performance as volatility is often associated with purely negative outcomes however volatility clearly refers to both unexpected negative as well as positive shifts in price.

Table 81. Simulation 8 – High Debt Farm - Descriptive Statistics of Risk Management Tool Costs

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,980	4,980	4,989	4,989	4,989	4,989	4,989	4,989
Mean	$81,736	$37,017	$311,591	$254,342	$291,292	$207,917	$170,967	$252,555
Standard Deviation	$47,034	$14,328	$158,444	$141,882	$152,007	$79,855	$66,261	$104,676
Median	$74,300	$36,750	$291,633	$233,145	$271,431	$205,466	$168,480	$246,069
5%	$18,903	$14,019	$89,574	$64,074	$81,330	$80,702	$65,760	$91,526
95%	$171,421	$61,383	$605,103	$522,276	$573,172	$344,350	$284,160	$436,200
Minimum	$5,000	$1,576	$12,000	$12,000	$12,000	$4,320	$4,320	$4,320
Maximum	$315,212	$83,690	$1,158,308	$1,101,005	$1,156,259	$565,972	$504,000	$782,789
Skew	0.9	0.19	0.82	0.97	0.87	0.19	0.22	0.37
Kurtosis	0.96	-0.3	1.03	1.52	1.21	-0.25	-0.18	-0.01

The "Cash / Options" strategy also provided the best downside protection as shown in the table below. In terms of absolute levels above the cash marketing strategy net farm income the "Options" strategy produced the most favorable results.

Table 82. Simulation 8 – High Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($29,524)	$94,255	$11,634	$44,812
Cash / Options	($12,890)	$36,532	$20,091	$37,680
Futures	($88,367)	$361,276	$55,169	$223,488
Futures / Cash	($86,187)	$304,146	$54,561	$170,629
Futures / Options	($87,620)	$340,110	$57,871	$210,903
Options	($65,422)	$210,411	$77,843	$204,414
Options/ Cash	($63,448)	$173,303	$75,216	$167,578
Options / Futures	($77,724)	$261,165	$71,145	$236,449

Table 83. Simulation 8 – High Debt Farm – Operating Line Borrowed

Strategy	Average Total Operating Line Borrowed	End of Year Operating Line - Average	End of Year Operating Line - Maximum
Cash	$1,056,208	$618,088	$1,559,258
Cash / Futures	$1,129,511	$700,922	$1,626,247
Cash / Options	$1,123,320	$661,217	$1,582,371
Futures	$1,344,432	$945,569	$2,014,235
Futures / Cash	$1,301,330	$887,515	$1,953,241
Futures / Options	$1,338,874	$926,696	$2,012,571
Options	$1,360,274	$857,685	$1,731,548
Options / Cash	$1,320,481	$817,127	$1,688,191
Options / Futures	$1,340,824	$891,312	$1,726,530

Table 84. Simulation 8 – High Debt Farm – Percent Change in Equity

Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	16.9%	-18.7%	59.9%
Cash / Futures	13.5%	-21.4%	57.2%
Cash / Options	15.1%	-19.9%	57.8%
Futures	2.6%	-24.4%	39.1%
Futures / Cash	5.4%	-22.3%	41.7%
Futures / Options	3.5%	-24.6%	39.5%
Options	6.8%	-23.5%	48.4%
Options / Cash	8.7%	-22.2%	50.0%
Options / Futures	5.2%	-24.8%	46.1%

The cash marketing strategy provided the highest average percent change in equity followed by the “Cash / Options” strategy. Across all strategies, funds borrowed against the operating line were approximately $200,000 greater than the results of the baseline simulation on average due to the simulated increased volatility.

Simulation 9 - High Debt Farm – 50% Milk Production Hedged

This simulation maintains all of the high debt farm baseline simulation parameters and assumptions with the exception of the hedge ratios used on milk production. For this simulation, like those performed for the low and average debt farms, it is assumed that only 50% of milk production is hedged. In general the average market and hedged prices generated in this simulation are comparable to historical data and other simulations in this work. Outlying values are found in the maximum prices of the May milk contract and the April and May soybean meal contracts.

Table 85. Simulation 9 – High Debt Farm – Market Prices

	Milk			Corn			Soybean Meal		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
January	$12.35	$8.63	$29.44	$2.75	$1.91	$20.17	$191.71	$139.75	$360.19
February	$12.28	$8.58	$25.91	$2.75	$1.71	$20.13	$191.71	$123.88	$393.51
March	$12.35	$7.82	$35.52	$2.75	$1.63	$19.28	$191.66	$112.07	$415.29
April	$12.46	$7.60	$24.22	$2.82	$1.58	$12.88	$195.68	$103.03	$2,243.24
May	$12.67	$8.38	$93.33	$2.82	$1.51	$13.54	$195.81	$98.82	$2,246.41
June	$12.98	$7.58	$54.44	$2.91	$1.47	$30.24	$208.25	$94.42	$910.65
July	$13.34	$7.88	$45.02	$2.91	$1.42	$31.27	$208.33	$88.30	$917.78
August	$13.60	$7.05	$38.59	$3.02	$1.26	$15.29	$210.45	$80.31	$787.08
September	$13.90	$7.44	$38.04	$3.02	$1.24	$14.18	$207.61	$78.64	$800.59
October	$13.60	$7.38	$49.35	$2.81	$1.29	$19.13	$201.50	$48.39	$812.22
November	$13.18	$7.04	$30.60	$2.81	$1.29	$18.52	$202.04	$76.58	$782.63
December	$13.01	$7.30	$38.31	$2.81	$1.25	$18.48	$202.03	$70.50	$791.66

Table 86. Simulation 9 – High Debt Farm – Hedging Summary

Commodity	Contract Month	Iterations Hedged	Average Opening Hedge Price	Maximum Opening Hedge Price	Minimum Opening Hedge Price
Milk	1	186	$16.96	$28.53	$15.65
	2	344	$16.01	$27.17	$14.66
	3	555	$15.97	$37.02	$14.61
	4	941	$15.27	$22.91	$11.99
	5	1,070	$15.83	$86.33	$13.52
	6	1,117	$16.36	$56.30	$14.57
	7	1,496	$13.71	$42.95	$8.43
	8	1,852	$13.82	$40.50	$9.17
	9	2,185	$13.58	$34.39	$8.57
	10	1,871	$15.89	$45.08	$14.47
	11	1,619	$15.72	$33.63	$14.48
	12	1,454	$15.87	$40.42	$14.44
Corn	2	308	$2.63	$6.35	$1.93
	3	474	$2.67	$5.77	$1.95
	4	936	$2.70	$7.16	$1.79
	5	1,067	$2.72	$6.92	$1.68
	6	1,058	$2.78	$6.37	$1.65
	7	1,425	$2.78	$10.87	$1.62
	8	1,775	$2.85	$8.13	$1.55
	9	2,125	$2.87	$10.54	$1.49
	10	1,811	$2.71	$10.73	$1.53
	11	1,568	$2.73	$10.12	$1.54
	12	1,406	$2.68	$9.05	$1.59
Soybean Meal	2	308	$191.79	$332.37	$141.73
	3	474	$190.61	$340.71	$122.85
	4	936	$200.27	$1,983.69	$126.81
	5	1,067	$196.67	$610.21	$120.29
	6	1,058	$207.21	$622.25	$108.16
	7	1,425	$206.15	$609.64	$111.03
	8	1,775	$207.50	$592.81	$90.65
	9	2,125	$202.84	$657.52	$91.91
	10	1,811	$198.03	$649.40	$88.85
	11	1,568	$200.40	$533.51	$92.37
	12	1,406	$198.17	$654.47	$88.67

Based upon the graph and table on the following page, the cash marketing strategy produced the highest average net farm income. The “Cash / Options” strategy allowed for the highest maximum net farm income. All strategies with the exception of the “Cash / Futures” and “Options / Futures” strategies succeeded in reducing the net farm income variance as measured by the coefficient of variation. Of note is the fact that the downside risk of the cash marketing strategy was not improved by the hedging strategies in this simulation. This could point to the need of more highly leveraged operations to increase the hedge ratios in their market plan in order to gain the benefit of downside protection.

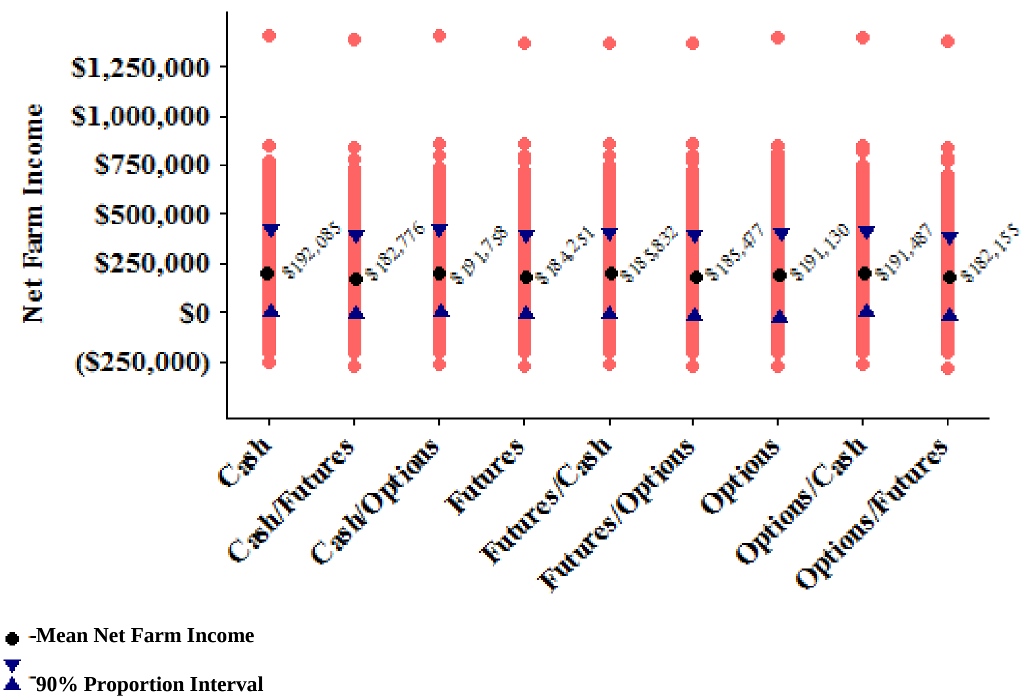

Figure 13. Simulation 9 – High Debt Farm – Net Farm Income

Table 87. Simulation 9 – High Debt Farm – Net Farm Income Summary

Marketing Strategy	Average	Standard Deviation	C.V.	Minimum	Maximum	5%	95%
Cash	$192,085	$133,594	69.55%	($257,939)	$1,403,383	($7,179)	$418,804
Cash / Futures	$182,776	$129,896	71.07%	($274,581)	$1,389,073	($10,186)	$406,482
Cash / Options	$191,758	$133,457	69.60%	($265,409)	$1,409,629	($7,865)	$418,131
Futures	$184,251	$126,777	68.81%	($273,516)	$1,362,054	($9,074)	$397,467
Futures / Cash	$185,832	$127,606	68.67%	($266,404)	$1,362,768	($8,289)	$402,310
Futures / Options	$185,477	$127,449	68.71%	($273,897)	$1,368,990	($9,711)	$398,760
Options	$191,130	$130,876	68.47%	($279,487)	$1,400,593	($8,155)	$412,869
Options / Cash	$191,487	$131,018	68.42%	($271,994)	$1,394,395	($6,996)	$415,654
Options / Futures	$182,155	$127,197	69.83%	($288,660)	$1,380,005	($9,685)	$398,021

As shown in the above table, hedging only 50% of the milk production provides additional exposure to the variance in the cash market which pushes the average net farm income just slightly ahead of the average net farm income in the full hedging results of Simulation 7.

Table 88. Simulation 9 - High Debt Farm – Marketing Strategy Total Risk Management Costs

Strategy	Average	Standard Deviation	C.V.	Maximum
Cash / Futures	$38,383	$25,783	67.2%	$244,586
Cash / Options	$12,825	$7,018	54.7%	$44,174
Futures	$77,950	$45,895	58.9%	$304,911
Futures / Cash	$51,264	$33,449	65.2%	$230,551
Futures / Options	$64,089	$39,168	61.1%	$261,089
Options	$42,097	$22,587	53.7%	$133,214
Options / Cash	$29,272	$15,864	54.2%	$94,320
Options / Futures	$67,656	$39,494	58.4%	$280,826

Table 89. Simulation 9 – High Debt Farm – Differences from Cash Marketing Strategy and Associated Returns

Strategy	Differences from Cash Strategy Results				Returns
	Average Net Farm Income	Standard Deviation	Range	90% Interval	Standard Deviation Difference from Cash
Cash / Futures	($9,302)	($3,698)	$2,333	($9,316)	9.63%
Cash / Options	($325)	($137)	$13,716	$12	1.07%
Futures	($7,827)	($6,816)	($25,751)	($19,443)	8.74%
Futures / Cash	($6,249)	($5,988)	($32,149)	($15,385)	11.68%
Futures / Options	($6,602)	($6,144)	($18,435)	($17,513)	9.59%
Options	($949)	($2,718)	$18,758	($4,960)	6.46%
Options / Cash	($595)	($2,575)	$5,068	($3,334)	8.80%
Options / Futures	($9,919)	($6,397)	$7,343	($18,278)	9.45%

The table on the following page contains information on the distribution of total costs for each of the risk management tool combinations. As expected, the average cost across all combinations decreased with the reduced hedge ratio used in this simulation.

Table 90. Simulation 9 – High Debt Farm - Descriptive Statistics of Risk Management Tools

	Cash / Futures	Cash / Options	Futures	Futures / Cash	Futures / Options	Options	Options / Cash	Options / Futures
Iterations	4,804	4,804	4,846	4,846	4,846	4,846	4,846	4,846
Mean	$39,949	$13,348	$80,427	$52,893	$66,125	$43,435	$30,202	$69,806
Standard Deviation	$25,087	$6,654	$44,431	$32,684	$38,056	$21,640	$15,218	$38,201
Median	$36,078	$12,740	$74,459	$47,473	$60,443	$41,509	$28,800	$65,549
5%	$6,617	$3,836	$18,971	$10,758	$14,825	$12,208	$8,400	$15,839
95%	$87,030	$25,449	$160,351	$113,296	$135,205	$81,463	$57,120	$139,318
Minimum	$5,000	$128	$6,000	$6,000	$6,000	$720	$720	$720
Maximum	$244,586	$44,174	$304,911	$230,551	$261,089	$133,214	$94,320	$280,826
Skew	1.02	0.58	0.81	1.05	0.92	0.53	0.57	0.7
Kurtosis	1.71	0.21	0.8	1.51	1.12	0.11	0.19	0.52

A closer look at the relative returns of the tool combinations reveals that the "Options / Cash" combination provides the highest potential returns above the cash marketing strategy on average. Conversely the "Futures" strategy provides the least negative returns on average when the hedged net farm income is below the cash marketing strategy value. These results are shown in the following table.

Table 91. Simulation 9 – High Debt Farm – Net Farm Income and Total Risk Management Costs Above and Below Cash Marketing Strategy Results

	Hedged Net Farm Income *below* Cash		Hedged Net Farm Income *above* Cash	
Marketing Tools	*Average Difference Below*	*Average Total Risk Management Costs*	*Average Difference Above*	*Average Total Risk Management Costs*
Cash / Futures	($13,713)	$45,953	$3,253	$19,782
Cash / Options	($5,076)	$13,111	$6,280	$13,712
Futures	($19,610)	$91,272	$11,025	$61,546
Futures / Cash	($18,143)	$63,090	$10,971	$36,916
Futures / Options	($19,111)	$75,878	$12,022	$50,387
Options	($14,391)	$43,114	$17,239	$43,903
Options/ Cash	($13,143)	$29,906	$16,529	$30,638
Options / Futures	($21,056)	$73,661	$14,721	$60,326

Table 92. Simulation 9 – High Debt Farm – Operating Line Borrowed

Strategy	Average Total Operating Line Borrowed	End of Year Operating Line – Average	End of Year Operating Line - Maximum
Cash	$918,137	$594,187	$1,252,240
Cash / Futures	$944,366	$630,786	$1,312,206
Cash / Options	$938,376	$608,491	$1,275,264
Futures	$999,618	$676,877	$1,377,402
Futures / Cash	$970,068	$647,588	$1,342,649
Futures / Options	$987,866	$662,427	$1,366,167
Options	$980,807	$641,788	$1,327,659
Options / Cash	$963,368	$627,241	$1,303,879
Options / Futures	$982,597	$663,355	$1,364,601

Table 93. Simulation 9 – High Debt Farm – Percent Change in Equity

Strategy	% Change in Equity - Average	% Change in Equity - Minimum	% Change in Equity - Maximum
Cash	16.9%	-4.0%	73.3%
Cash / Futures	15.3%	-5.5%	71.6%
Cash / Options	16.3%	-4.4%	72.7%
Futures	13.3%	-6.0%	67.3%
Futures / Cash	14.6%	-4.9%	68.4%
Futures / Options	14.0%	-5.3%	67.8%
Options	14.9%	-5.0%	70.1%
Options / Cash	15.5%	-4.6%	70.7%
Options / Futures	13.9%	-6.2%	69.1%

Comparable to all other simulations, the cash marketing strategy allowed for the greatest potential percent change in equity due to its low level of new borrowings. The “Cash / Options” strategy was second with an average percent change of 16.34%. The “Futures” strategy had the highest potential maximum operating line borrowed, more the $400,000 above the second highest amount associated with the “Futures / Options” strategy.

Summary of Results

This chapter presented results of three marketing scenarios across three levels of debt making for a total of nine simulations of 5,000 iterations each. Results presented included the market prices and opening hedged prices generated in each simulation, the resulting net farm income of all risk management strategies, costs and a simple return measure for all risk management tool combinations used in this work, additional liabilities incurred as a result of investing in risk management tools, and finally the percent change in equity was presented as a measure inclusive of both net farm income and borrowings required to meet hedging costs.

In general results are in line with the predicted lower net farm income associated with hedging but reduced variation over the long term. Interpretation of the results is deemed to be influenced by the framing of the risk management decision process. Strategies and marketing tool combinations differed in their evaluation according to the measure of success used. Measures included those related to absolute net farm income levels as well as those related to the variance reduction in net farm income.

Across debt levels net farm income decreased as debt level increased, however the variance in net farm income was relatively comparable among all simulations at the absolute level. In light of the decreasing average net farm income though, the coefficient of variation increased as debt levels increased. Risk management tools did decrease the standard deviation of net farm income by slightly increasing amounts as debt levels grew, which would represent greater percentages of net farm income for higher debt farm. Thus it could be said that risk management tools protect a greater proportion of net farm income as debt level rises.

While borrowings against the operating line did increase across debt levels this likely due mainly to the associated increase in total debt obligations as any low price environments would push a higher debt farm with lower equity to borrow sooner than a lower debt farm. Total risk management costs remained relatively stable across debt levels among similar simulations. These results point to the conclusion that higher debt farms may have greater incentive to hedge. Based on the relatively stable costs of risk management, the variance reductions provided to higher debt farms provides a higher return as each dollar in variance reduction represents a higher proportion of expected net farm income. These increasing returns are shown in the tables presented earlier.

General Recommendations

Evaluating and recommending specific risk management tools requires knowledge of the goals and preferences of the decision maker. Based upon the results presented in this work, a decision maker would have a firm foundation for choosing an options based strategy if the end goal was to preserve opportunities for maximum net farm income while protecting against downside risk but would also be completely justified in the use of futures contracts if the desired outcome was to achieve the greatest reduction in net farm income variation over the long term.

Some differences though do exist between the strategies and marketing tool combinations presented in this work. The costs between each of the general groups of marketing tools, cash, futures, and options can potentially differ considerably. One way to look at these costs is to think of them as substitute risks. In this sense, the decision maker is exchanging risk in the cash marketplace with the risk of potential costs associated with the various risk management tools. One could differentiate between the use of futures and options according to the nature of their costs. With respect to futures, costs are not fixed and may vary dramatically as shown within this work. One could use stop-loss instructions in order to limit the potential costs associated with futures contracts. However, while this approach reduces some risk of uncontrolled costs it does not necessarily guarantee it. Alternatively the use of options incurs a fixed cost, similar to an insurance policy. The decision maker may then use this notion to assist in differentiating between the use of these tools, which may be especially beneficial if the decision maker is impartial between other measures such as maximum net farm income and reduction in the variance of net farm income.

In addition, a decision maker analyzing these results should keep in mind that absolute net farm income levels affect the financial well-being of the operation while variance reduction in net farm income is not directly realized. In other words, the fact that the variance in net farm income was decreased using strategies employed in this work is based on several 5,000 iteration simulations. In reality however a decision maker works with a much smaller sample space assuming each of the iterations in a simulation is comparable to a single marketing year. Thus, while in the long run variance is reduced it is possible that in the short term the results of a risk management strategy will be minor reductions in variance at a high cost. Again, decision makers must weigh those factors that are most important to their own situation.

CHAPTER VI: CONCLUSIONS

This thesis analyzed the use of market risk management strategies and tools for dairy farms through the use of simulation techniques. Pro-forma financial statements were constructed as a medium for this analysis. Simulations were designed to mimic the price environment faced by dairy managers from 2003 through 2008. Results indicate that variance in net farm income can be reduced through the use of risk management tools. Specific levels of hedging, which best fit any one operation, will depend on the preferences of the dairy manager and the characteristics of the operation.

In sum, those strategies using cash marketing to price milk production had the highest variance in net farm income. The use of futures contracts provides the greatest reduction in net farm income variance but is accompanied by the highest total costs on average. While options based strategies do not reduce net farm income variance as greatly as futures contracts, they do provide comparable minimum net farm income protection while at the same allowing for higher upside potential of net farm income than is found in the results for strategies based on futures contracts. The use of options in averting market risk has lower total costs, which are also not as variable as the costs associated with futures contracts. However, strategies using options typically had lower returns. In general hedging only fifty percent of the milk production resulted in higher returns on investment as average costs decreased from the levels associated with full hedging by a greater amount than did the average reduction in net farm income standard deviation through the use of risk management tools.

This work provided a unique extension to the literature by explicitly considering the full distributions of the costs and benefits of hedging. In addition, this work used a selective hedging strategy based upon the financial situation of the dairy farm. Areas for additional research include sensitivity analysis across several parameters such as price volatility, marketing triggers, and hedging ratios as well as comparison across various marketing philosophies including calendar based approaches.

The use of risk management tools is not a costless activity and typically results in lower levels of net farm income in the long run. Therefore the decision maker may be better served to frame risk management as a means rather than an end. While reducing variance in net farm income has value, as discussed earlier in this work variability in net farm income is not inherently a risk (Shadbolt and Martin). Instead, it may behoove decision makers to think of risk management as a method to achieve some other goal, for instance a less variable income stream may increase the attractiveness of another capital investment or complement desired production strategies (Johnson and Boehlje). Market risk management tools can provide dairy managers with greater control over some of the price volatility they face with respect to milk and feed prices. The effects of the various risk management tool combinations examined in this work vary in the manner in which they provide this control as well as their associated costs. While the use of futures contracts provides greater variance reduction overall, the use of options allows for upside potential in net farm income. Along with this, while futures offer lower initial costs and thus a greater leverage effect than option, on average though futures contracts have higher costs with wider variances than do options. These characteristics should be strongly considered by dairy managers in choosing their preferred strategy for managing price risks.

While this work presents a unique structure for modeling the performance of various market risk management tools, it does allow for additional research opportunities. Although the action of the marketing strategy, to hedge when the desired income over purchased feed cost is generated within the simulation, represents a novel approach to modeling the strategic choices of a decision maker future work would complement the results of this work by simultaneously evaluating other marketing actions such as those based on time or the position of current prices relative to historic measures. Including these types of marketing actions would allow for comparisons against those strategies previously examined in the literature regarding risk management on dairy farms.

Perhaps one of the most important areas for further research relates to the psychological structures behind decisions based on incomplete information. The benefits of increased knowledge in this area are several fold but would especially benefit decision makers in improving their own decision making processes and would also allow for the development of more individually tailored risk management products. The simulation techniques and model structure used in this model are well tailored to elicitation of preferences as the model is structured in a whole farm manner. Thus a dairy manager can observe the effects of isolated variables on the entire operation while at the same being able to efficiently learn from the virtual experience provided through the simulation techniques.

REFERENCES

Arias, J., B. Brorsen, and A. Harri. "Optimal Hedging Under Nonlinear Borrowing Cost, Progressive Tax Rates, and Liquidity Constraints." *The Journal of Futures Markets.* 20 (2000): 375-396.

Bailey, K. "Using Milk Futures to Lock in Profitability." Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University, Dairy Risk-Management Education, 2007.

Bailey, K. and V. Ishler. "Tracking Milk Prices and Feed Costs." Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University, Dairy Risk-Management Education, 2007.

Bamba, I. and L. Maynard. "Hedging-Effectiveness of Milk Futures Using Value-At-Risk Procedures." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri, 19-20, April, 2004.

Bernhardt, K. "Introduction: What is a Marketing Plan?" University of Wisconsin Farm and Risk Management Team, Achieving Risk Management Success, 2004.

Bernhardt, K. and D. Sutter. "Developing Pricing Protocols (Predetermined Marketing Rules)." University of Wisconsin Risk Management Team, Achieving Risk Management Success, 2001.

Betz, R. "Risk Management and Crop Insurance" (presentation). www.msu.edu/~betz/riskmgt/index.htm. (2002). Last accessed 3/16/09.

Betz, R. and B. Robb. "Dairy Cash Flow" (spreadsheet). www.msu.edu/~betz/financialmgt/index.htm. (2003). Last accessed 3/16/09.

Bosch, D. and C. Johnson. "An Evaluation of Risk Management Strategies for Dairy Farmers." *Southern Journal of Agricultural Economics.* 24 (1992): 173-182.

Chang, H., et al. "Quantifying Sources of Dairy Farm Business Risk and Implications for Risk Management Strategies." Department of Applied Economics and Management, Cornell University, Working Paper 2007-11, July 2007.

Clemen, R.T. and T. Reilly. *Making Hard Decisions.* Pacific Grove, CA: Brooks/Cole, 2001.

Collins, R.A. "Toward a Positive Economic Theory of Hedging." *American Journal of Agricultural Economics.* 79 (May 1997): 488-499.

Damodaran, A. *Strategic Risk Taking: A Framework for Risk Management.* Upper Saddle River, NJ: Wharton School Publishing, 2008.

Drye, P. and R. Cropp. "Price Risk Management Strategies for Dairy Producers: A Historical Analysis." Department of Agricultural and Applied Economics, University of Wisconsin, July 2001.

Garcia, A. et al. "High Priced Corn and Dairy Cow Rations." *Extension Extra.* South Dakota State University Cooperative Extension Service. (2007): 4035.

Holton, G. "Defining Risk." *Financial Analysts Journal.* 60 (2004): 19-25.

Internal Revenue Service. "Farmer's Tax Guide." Department of the Treasury, Publication 225, 6, November, 2008.

Johnson, D. and M. Boehlje. "Managing Risk by Coordinating Investment, Marketing, and Production Strategies." *Western Journal of Agricultural Economics.* 8 (1983): 155-169.

Jesse, E. and J. Schuelke. "Effectiveness of 'Naïve' Class III Hedging Strategies." Department of Agricultural and Applied Economics, University of Wisconsin, Marketing and Policy Briefing Paper 87, November 2004.

Karszes, J., C. Wickswat, and F. Vokey. "Dairy Replacement Programs: Costs and Analysis December 2007." Department of Applied Economics and Management, Cornell University, Extension Bulletin 2008-16, September 2008.

Klose, S. and J. Outlaw. "Financial and Risk Management Assistance: Decision Support for Agriculture." *Journal of Agricultural and Applied Economics.* 37 (2005): 415-423.

Knoblauch, W. et al. "Dairy Farm Management Business Summary New York State 2007." Department of Applied Economics and Management, Cornell University, Research Bulletin 2008-03, October 2008.

Knoblauch, W., L. Putnam, and J. Karszes. "Dairy Farm Management Business Summary New York State 2006." Department of Applied Economics and Management, Cornell University, Research Bulletin 2007-01, October 2007.

Knoblauch, W., L. Putnam, and J. Karszes. "Dairy Farm Management Business Summary New York State 2005." Department of Applied Economics and Management, Cornell University, Research Bulletin 2006-06, October 2006.

Lien, G. "Assisting Whole-farm Decision Making through Stochastic Budgeting." *Agricultural Systems.* 76 (2003): 399-413.

MacDonald, J. et al. “Profits, Costs, and the Changing Structure of Dairy Farming.” Economic Research Service, United States Department of Agriculture, Economic Research Report 47, September 2007.

Mandelbrot, B. “The Variation of Certain Speculative Prices.” *The Journal of Business.* 36 (1963): 394-419.

Manfredo, M. and T. Richards. “Cooperative Risk Management, Rationale, and Effectiveness: The Case of Dairy Cooperatives.” *Agricultural Finance Review.* 67 (2007): 311-339.

Maynard, L., C. Wolf, and M. Gearhardt. “Can Futures and Options Markets Hold the Milk Price Safety Net? Policy Conflicts and Market Failures in Dairy Hedging.” *Review of Agricultural Economics*. 27 (2005): 273-286.

Miller, A. et al. “Risk Management for Farmers.” Department of Agricultural Economics, Purdue University, Staff Paper 04-11, September 2004.

Miller, J. and D. Blayney. “Dairy Backgrounder.” Economic Research Service, United States Department of Agriculture, Electronic Outlook Report, July 2006.

Pennings, J. et al. “Producers’ Complex Risk Management Choices.” *Agribusiness* 24(2008): 31-54.

Russo, J. and P. Schoemaker. *Winning Decisions: Getting it Right the First Time.* Random House, Inc., 2002.

Shalloo, L. et al. “Description and Validation of the Moorepark Dairy System Model.” *Journal of Dairy Science.* 87 (2004): 1945-1959.

Stevenson, R. and R. Bear. “Commodity Futures: Trends or Random Walks?” *The Journal of Finance.* 25 (1970): 65-81.

Stephenson, M. and C. Nicholson. “An Analytical Review of a Refundable Assessment Plan for Dairy Producers.” Cornell Program on Dairy Markets and Policy, Department of Applied Economics and Management, Cornell University, 2007.

Taleb, N. *The Black Swan: The Impact of the Highly Improbable.* New York: The Random House Publishing Group, 2007.

Taleb, N. *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets.* The Random House Publishing Group, 2004.

Tauer, L. “Risk Preferences of Dairy Farmers.” *North Central Journal of Agricultural Economics.* 8 (1986): 7-15.

Tomek, W.G. and H.H. Peterson. “Risk Management in Agricultural Markets: A Review.” *Journal of Futures Markets.* 21 (2001): 953-985.

Tomek, W.G. and H.H. Peterson. "Implication of Commodity Price Behavior for Marketing Strategies." *American Journal of Agricultural Economics.* 87 (2005): 1258-1264.

Trapp, J.N. "A Commodity Market Simulation Game for Teaching Market Risk Management." *S. Journal of Agricultural Economics.*21 (1989): 139-147.

Turvey, C. and G. Power. "The Confidence Limits of a Geometric Brownian Motion." Selected Paper prepared for presentation at the American Agricultural Economics Association Meeting, Long Beach, California, 23-26, July, 2006.

Wang, D. and W. Tomek. "Characterizing Distributions of Class III Milk Prices: Implications for Risk Management." Department of Applied Economics and Management, Cornell University. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, 24-27, July, 2005.

Wilson, P., T. Luginsland, and D. Armstrong. "Risk Perceptions and Management Responses of Arizona Dairy Producers." *Journal of Dairy Science.* 71 (1988): 545-551.

Winston, W. *Simulation Modeling using @Risk.* Pacific Grove, CA: Brooks/Cole, 2001.

Winston, W. *Financial Models using Simulation and Optimization.* Ithaca, NY: Palisade Corporation, 2006.

Zylstra, M., R. Kilmer, S. Uryasev. "Risk Balancing Strategies in the Florida Dairy Industry: An Application of Conditional Value at Risk." Selected paper for presentations at the American Agricultural Economics Association Annual Meeting, Montreal, Canada, 27-30, July, 2003.